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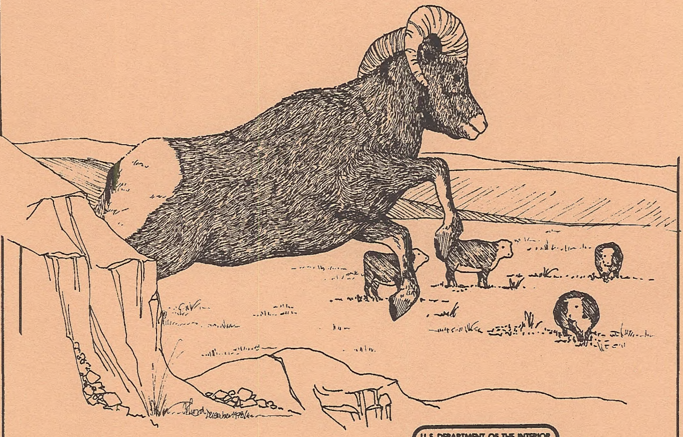

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To: AFOs

From: Service Center Director

Subject: Trickle Mountain Research Study - Final Report

Enclosed is the final report on the Trickle Mountain Research Study. The study was funded by the Bureau through a contract to Colorado State University. Several Bureau employees participated in the project in designing the study and by providing field support, as well as in conducting the research.

The study was designed to address some site specific management problems on the Trickle Mountain Wildlife Habitat Area, as well as to develop techniques for more general application in the Bureau. A major effort of the project was the development of a rangeland simulation model that can be used to predict the impact of various management actions on rangeland vegetation and on the capability of an area to support big game species.

A list of other publications resulting from the project can be found on page 132 of the final report. Copies of these papers are available from Allen Cooperrider, Denver Service Center (D-472).

Robert H. Andorfer

ASCD, Technical & Scientific Systems

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FINAL REPORT: TRICKLE MOUNTAIN RESEARCH STUDY

Contract No. YA-512-CT8-22

September 30, 1982

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ABSTRACT

A study was conducted to determine competitive interactions of six wild and domestic ungulates on a range in southern Colorado and to develop a system for forage allocation. Seasonal food habits and habitat use for bighorn sheep, pronghorn antelope, mule deer, elk, horses and cattle were determined over a two-year period. Plant species composition and forage production was measured. A simulation model was developed to integrate these data with data on animal numbers, dynamics, nutritional requirements of animals, and nutritional content of forages to predict consequences of alternative forage allocations. The simulation model can be applied to other areas with different forage composition and/or different species of ungulates.

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I. INTRODUCTION

A. Background of Project

The Trickle Mountain Research Study began in January 1978, under contract to Dr. James A. Bailey of Colorado State University. It was unique in that a U.S. Bureau of Land Management (BLM) employee, Allen Cooperrider, was assigned to CSU to work on the project and to expedite the technology transfer of research results to Bureau problems and programs.

B. Objectives

The objectives of the study were:

1. To determine food habits, habitat use, and dietary overlap of all domestic and wild ungulates on the Trickle Mountain Wildlife Habitat Area.
2. To map vegetation and determine species composition and forage production.
3. To determine gross carrying capacity for all ungulate species.
4. To suggest range habitat improvement practices.
5. To develop a forage allocation system.

C. Acknowledgments

Many people contributed their time and talent to the project and to this final report. Ed Roberts, Mark Strong, Richard Kerr, and Dale Hoffman of the BLM, and the late Dr. Douglas Gilbert of Colorado State University were instrumental in initiating the project.

Jeffrey Todd of AMAX Corporation, Dr. Richard Hansen of Colorado State University, and Gene Schoonfeld and Robert Hoover of the Colorado Division of Wildlife provided useful information on the history of the ungulates in the area. James OHerman of the Colorado Division of Wildlife provided useful data on the population dynamics and herd management objectives for the area.

Scott Hoover, Becky Trentlage, Gary Glueckert, Kim Foiles, and Mark Mastellar served on summer field crews collecting vegetation data. Special appreciation is extended to Scott "Hondo" Hoover who very capably served as a range technician in the summer of 1978 and returned to finish the job in the summer of 1979 as crew leader.

Becky Trentlage, Tom Lankenau, Gary Glueckert, Martha Cerny, Henry DuFour, Ed Rodriguez and Cathy Phillips all assisted in compiling and analyzing data.

Becky Trentlage worked on the project in various capacities in both the field and office for most of the project, and her energetic and enthusiastic efforts on many very tedious tasks is greatly appreciated.

The late Gary Lucich and Els Cooperrider of the Composition Analysis Laboratory at Colorado State University did most of the microhistological work for food habits determinations, and their concern for accuracy and careful attention to detail is most appreciated.

Scott McCollough assisted with the collection of vegetation data in the summer of 1978 and had lead responsibility for field work from January through December 1979. His master's thesis, "Impact of Cattle Grazing on Bighorn Sheep Habitat at Trickle Mountain, Colorado" is a major product of the project.

Many people in field offices assisted in various ways. Clay Bridges of the Canon City District, BLM, served as contract inspector and supported the project in many ways, as did John Schwarz, Royce Wheeler and Steve Hannen of the Alamosa Area Office, BLM. Tom Holland of the U.S. Forest Service in Saguache provided much useful information on the area when the project was being initiated.

Phyllis Turner of Colorado State University and Marlene Brooke and Christy Fischer of the BLM Service Center provided excellent support in typing the many drafts of this final report as well as numerous earlier progress reports and technical papers. Shirley McCullough prepared most of the illustrations.

Dr. Richard M. Hansen of Colorado State University provided much useful advice and assistance throughout the project and his support is most appreciated.

Allen Cooperrider wishes to thank his various supervisors at the BLM Service Center for their support and encouragement during the study--Dr. Dale Hoffman, Richard Kerr, Herb Runkel and John Baker--as well as John Crawford of the Washington Office, BLM. In particular, the advice and support of Richard Kerr throughout the study is most appreciated.

D. Overview

The project consisted of two rather distinct subprojects, a field study and development of a general grazingland model. Recognizing that many readers may be primarily interested in only one of these subprojects, an overview of the report is provided here.

Individual chapters are basically designed to address the objectives as listed in subsection B of this section. Those readers interested in aspects of the field study (Sections III through V) may benefit from first reading Section II on the study area.

Section III reports on food habits of the six ungulate species on the Trickle Mountain area. This task was a major portion of the project and is one of the most comprehensive studies of food habits of sympatric ungulates in North America. Further information on variability in food habits and on methodology for such studies is provided in papers by Cooperrider et al. (1981a) and Cooperrider et al. (1981b).

Section IV discusses habitat use of the Trickle Mountain ungulates, and Section V covers dietary overlap and potential for competition. Competition is also discussed in papers by Cooperrider and Bailey (1982a), McCollough et al. (1981), and McCollough (1982).

In Section VI the range survey data is presented and gross range carrying capacity is calculated by two methods.

Section VII presents the forage allocation simulation model developed. This section is substantially the same as a paper presented to the National Academny of Science Symposium on Forage Allocation (Cooperrider and Bailey 1980) and can be read independently from the other sections. The allocation model and various applications are also described in Cooperrider and Bailey (1981).

A variety of recommendations, both site-specific and general, for both management, and research and development, are presented in Section VIII.

II. STUDY AREA

A. Location

The Trickle Mountain study area is located in south-central Colorado approximately 20 km west of Saguache (Fig. 1). The study area, including all seasonal ranges of the Trickle Mountain bighorn sheep herd, is bounded on the north by the Continental Divide, on the south and west by Colorado Highway 114 and on the east by a line running south from Antora Peak (Fig. 2). The area measures about 30 km by 15 km and consists of approximately 45 percent lands administered by the BLM and 45 percent U.S. Forest Service lands. The remaining 10 percent of land is privately owned, mostly along creeks at lower elevations (Fig. 3).

B. Administration

The BLM lands are within the San Luis Resource Area of the Canon City District. The Forest Service Lands are within the Saguache Ranger District of the Rio Grande National Forest.

C. Topography

The BLM lands at lower elevations are characterized by mesas topped by rolling hills and steeply dissected by drainages. Volcanic rock outcrops are associated with mesa edges as "rimrock" cliffs and ledges and with some ridge tops. Open grassy slopes are common on the mesa tops and lower slopes and hilltops.

The creek bottoms are mostly narrow with flat floodplains bordered by talus slopes climbing steeply to mesa rimrocks. The area, generally, slopes to the southeast until Saguache Creek empties into the San Luis Valley bottom.

Elevations range from 2,400 m (7,840 ft) along Saguache Creek, in the southeast to 4,100 m (13,266 ft) on Antero Peak. Elevations on BLM-administered lands range from about 2,500 to 3,200 m (8,000 to 10,400 ft). The Continental Divide is generally around 3,700 m (12,000 ft) elevation.

D. Geology and Soils

Surface rocks of the study area are predominantly Tertiary volcanic rocks overlying Precambrian crystalline and sedimentary rocks (Bruns et al. 1971, Shepherd 1975).

Six soil mapping units have been distinguished on the area (Heil et al. 1977) as follows:

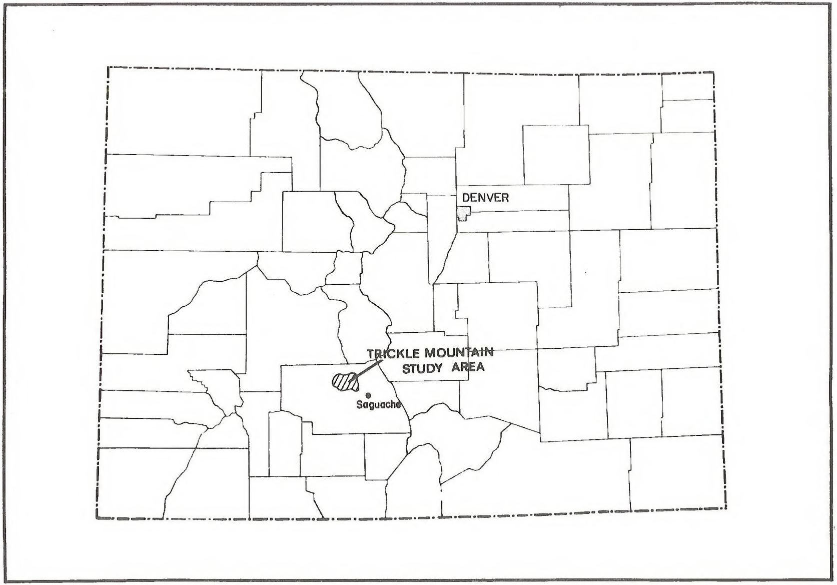

Figure 1. Location of Trickle Mountain Study Area, Saguache County, Colorado.

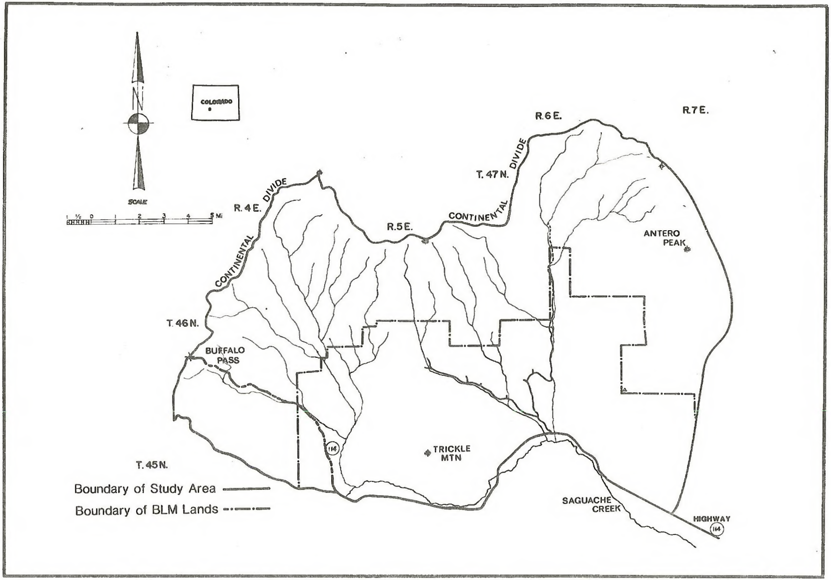

Figure 2. Trickle Mountain Study Area.

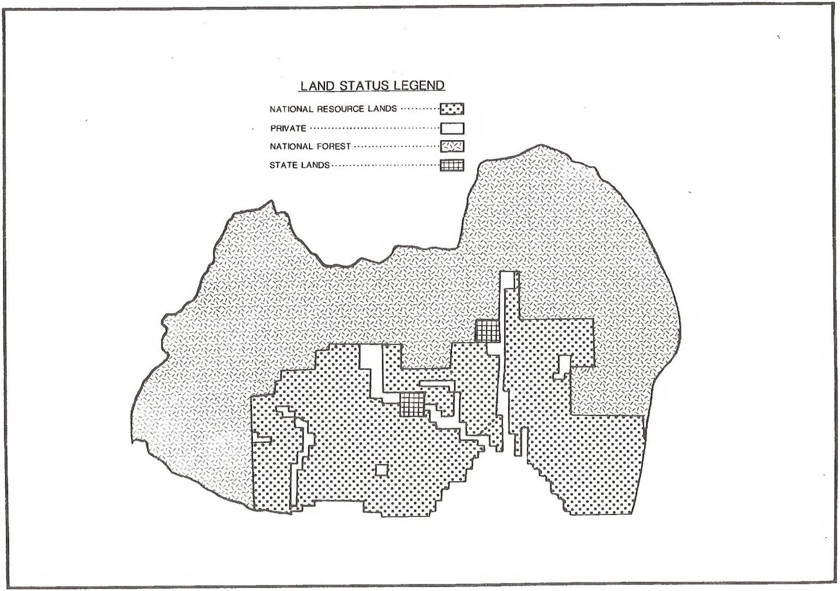

Figure 3. Land ownership of Trickle Mountain Study Area.

(1) Typic Cryoboralfs, skeletal - Rock Outcrop. These are found at the Higher elevations around Antora Peak, largely on Forest Service land.

(2) Typic Haplargids, loamy-Typic Torriorthents, skeletal. These are the most common soils on the lower elevation BLM lands.

(3) Borollic Haplargids - Borollic Calciorthids. These soils are found at the lower elevations along Saguache Creek at the southern edge of the study area.

(4) Aridic Argiborolls - Lithic Argiborolls. These soils are found at intermediate elevations on Forest Service and BLM lands on the eastern half of the study area.

(5) Argic Cryoborolls - Typic Cryoborolls. These soils are found at intermediate and higher elevations on the western half of the study area.

(6) Lithic Haploborolls, skeletal - Rock Outcrop. These soils are found at higher elevations on Forest Service land along the northern edge of the study area.

Detailed descriptions of these soil units are found in Heil et al. (1977). A soil survey of the area has been conducted by the Soil Conservation Service and is being published.

E. Climate

The Trickle Mountain study area has a relatively mild, dry climate with a growing season of about 100 days. Temperatures vary from a high mean of about 65°F (18°C) to a low mean of about 19°F (-7°C). Winds are normally strong from the west and northwest during winter and spring.

Precipitation comes in the form of winter snow and spring-summer thunderstorms. The greatest precipitation normally comes in August, with the July-August-September period being the wettest of the year. Average annual precipitation for the BLM portion of the study area varies from 20-40 cm (8-16 in) depending on elevation and local topography. Precipitation exceeds 88 cm (35 in) per year in the highest elevations, on Antora Peak.

Weather records for 30 years are available for the town of Saguache, located approximately 25 km (15 mi) southeast of the center of the study area at an elevation of 2,368 m (7,697 ft).

F. Vegetation

Vegetation varies from riparian meadows along Saguache Creek and its tributaries at the lowest elevations to alpine meadows on Antora Peak. Other major vegetation types within the area include shortgrass, pinyon-juniper, ponderosa pine-bunchgrass, Douglas fir, aspen, and sub-alpine meadow. Shepherd (1975) described the vegetation of some bighorn sheep ranges in the area. A more complete description of the vegetation can be found in Section VI.

G. Fauna

1. General

The Trickle Mountain area contains a high diversity of wildlife. Due to its location and topography, the fauna includes species typical of the Great Plains, the southwest desert and of the southern Rocky Mountains. For example, there are roughly 14 species of corvids (Crow-like birds) in the U.S., 3 of which have very limited distributions. Of the remaining 11 species, 8 occur in the Trickle Mountain area (Gray Jay, Stellar's Jay, Scrub Jay, Black-billed Magpie, Common Raven, Common Crow, Pinon Jay, and Clark's Nutcracker[1]); this pattern of diversity holds for several other groups of plants and animals.

A wildlife habitat management plan for the BLM lands in the area was prepared in 1977. Wildlife species designated to receive priority in management include Abert squirrel, Rio Grande cutthroat trout, prairie falcon, and golden eagle in addition to the wild ungulates. The discussion here will be limited to the wild and domestic ungulates.

2. Ungulates

A diversity of ungulate species are present on the area, including bighorn sheep, pronghorn antelope, mule deer, and elk. In addition, bison were present historically and apparently moved between the San Luis Valley to the Gunnison River drainage by traveling up Saguache Creek and over Cochetopa Pass (Heap 1954).

a. Bighorn Sheep

The history of bighorn sheep in Colorado has been documented by Moser (1962) and Bear and Jones (1973). Journals of early explorers indicated there were great numbers of bighorn sheep in the mountainous areas of Colorado. However, by 1900 the combination of overhunting and competition from domestic livestock had reduced the population. The Colorado legislature officially closed the bighorn season in 1887 and it was not reopened until 1953. There were an estimated 7,230 bighorn sheep in Colorado in 1915, 3,200 in 1958, and 2,200 in 1970 (Seton 1929; Moser 1962; Bear and Jones 1973). Since 1970, many herds have increased and others have been reestablished with transplants. The Trickle Mountain bighorn sheep herd has generally followed this pattern (Table 1).

[1] Scientific names of all species mentioned in the text are given in Appendix A.

When Capt. Gunnison traveled from the San Luis Valley up Saguache Creek and over Cochetopa Pass in late August 1853, Dr. James Schiel, a German geologist accompanying the expedition reported that "sizeable herds of mountain sheep appeared often on the high ridges, avoiding all pursuits by their never-tiring watchfulness" (Mumey 1955:77). At this time, the San Luis Valley was already settled and livestock grazing was widespread (Bean 1975).

Table 1. Estimated numbers and harvest of bighorn sheep, Trickle Mountain, Colorado.

Year	Number Counted	Number Estimated	Harvest	Source
1898	--	60-80	---	Cowan (1940)
1928	38	---		Bear and Jones (1973)
1930-1950		0		Bear and Jones (1973)
1951	15	15		Bear and Jones (1973)
1953			4	Bear and Jones (1973)
			Season Closed (1954-1957)	
1958			1	Bear and Jones (1973)
1959			3	Bear and Jones (1973)
1960			6	Bear and Jones (1973)
1961	36		1	Bear and Jones (1973)
1962			4	Bear and Jones (1973)
1963			4	Bear and Jones (1973)
1964			1	Bear and Jones (1973)
1965	48	125	7	Bear and Jones (1973)
1966	77		1	"
1967	98		6	"
1968	117		6	"
1969	111		3	"
1970	114		6	"
1971	122	165-175	---	Bear and Jones (1973)
1980		350		Olterman (1960)

In the next 50 years, increased settlement and the discovery of gold in various lodes surrounding the valley increased the numbers of people in the valley and surrounding areas. The combination of increased livestock grazing and indiscriminate hunting probably contributed to a decline of this herd during this period.

In 1898 Dall de Weese of Canon City, Colorado, reported to C. Hart Merriam that there were 60 to 80 bighorn sheep in the Cochetope Mountains west of Saguache (Cowan 1940). The last reported sighting of sheep in this area, prior to reintroduction, was of 38 animals at Baldy Lake in 1928 (Bear and Jones 1973). The precise reason for the decline of the sheep herd is not known. Presumably, hunting and livestock grazing played a role. In addition to competition for forage with livestock, diseases from domestic sheep may have contributed to the decline. Prior to 1950 there was considerable grazing of domestic sheep (Shepherd 1975). The original grazing license for the Trickle Mountain allotment, issued in 1937 only a few years after the Taylor Grazing Service was formed, was for 1,000 AUMs used with 5,000 sheep (Haszier 1963).

On February 15, 1951, 15 sheep (8 ewes, 4 lambs, and 3 rams) were reintroduced on Saguache Creek (Bear and Jones 1973). In 1961, 36 sheep were counted and by 1965, 48 sheep were counted; the estimated total population was 125 sheep (Bear and Jones 1973).

The population continued to increase and was estimated at 350 animals in 1980 (Table 1). A hunting season was first held in 1953, and then was closed from 1954 to 1957. From 1958 until present a limited rams-only season has been held with from 1 to 7 animals being harvested annually (Table 1).

In addition, approximately 180 sheep from the Trickle Mountain herd have been trapped and transplanted to other areas from 1971 to 1980 (Widhalm 1981). The Trickle Mountain herd was considered by Bear and Jones (1973) to be one of the most productive herds in the state.

The BLM's management objectives for bighorn sheep in the area are to:

> "Improve habitat conditions . . . to support the bighorn sheep population which utilizes the crucial winter range around Trickle Mountain from 300 to 350 head (or to 500 head if it becomes possible later without precipitating a lungworm related dieoff)."

and to

"Protect 1,800 acres of crucial bighorn sheep winter range and provide additional winter forage." (Prichard et al. 1977.)

b. Pronghorn Antelope

Hoover et al. (1959) reviewed the history of pronghorn antelope in Colorado. Due primarily to hunting, including substantial market hunting, antelope in Colorado declined from an estimated 2 million in 1860 to 25,000 in 1898 (Hoover et al. 1959). In 1899 the season was closed and remained closed until 1945. By 1918, pronghorn numbers had declined to under 1,000 in Colorado. They then increased slowly until 1957 when numbers were estimated at 10,000. The antelope of the San Luis Valley and Trickle Mountain followed this pattern (Table 2).

Table 2. Estimated numbers and harvest of pronghorn antelope, Trickle Mountain, Colorado.[1]

Year	Number Counted	Number Estimated	Harvest	Source
1939	0	0		Hoover (1979)
1942	0	0		Hoover (1979)
1949	35	35		Till (1950)
1967		111	27	Olterman (1980)
1968		92	35	Olterman (1980)
1969		90	23	Olterman (1980)
1970		96	17	Olterman (1980)
1971		96	8	Olterman (1980)
1972		114	13	Olterman (1980)
1973		100	13	Olterman (1980)
1974		122	12	Olterman (1980)
1975		136	14	Olterman (1980)
1976		143	27	Olterman (1980)
1977		184	4	Olterman (1980)
1978		199	4	Olterman (1980)
1979		178	21	Olterman (1980)

[1] The numbers for 1967 and later are for Data Analysis Unit A-73; Olterman (1980) estimates that 75% of this herd resides within the Trickle Mountain study area.

Lt. Zebulon Pike reported seeing thousands of antelope in the San Luis Valley when he traveled through the region i the 1850's (Hoover 1979). By the early 1920's antelope were absent from the valley, except for a remnant herd of about 40 from near Crestone (Nelson 1925). Statewide surveys by the Colorado Game and Fish Department in 1939 and 1942 failed to locate antelope in Saguache County.

Antelope were reintroduced to Saguache County by the Colorado Game and Fish Department starting in 1949. Twenty-eight animals, consisting of 12 bucks, 10 does and 6 fawns, were released north of Saguache on December 14; and an additional 2 bucks, 3 does and 2 fawns were released on December 28, bringing the total released at this site to 35 head (Till 1950).

Two additional antelope transplants were made in Saguache County. Twelve animals, including 1 buck, 2 does and 9 fawns, were released at Hot Springs, 23 miles west of Saguache, on November 24, 1953; and 31 head, consisting of 7 bucks, 16 does and 8 fawns, were released 8 miles southeast of Villa Grove in 2 releases on December 11, 1953, and February 4, 1954 (Ogilvie 1954). The ranges of the original Saguache transplant and the Villa Grove transplant were found to overlap soon after the latter were released (Hoover 1979a).

From these transplants, a herd of approximately 150 animals has been established in the Trickle Mountain area. Population estimates and hunting statistics of the Colorado Division of Wildlife for Unit A-73 which contains the Trickle Mountain area years indicate that, for the last 13 years, the post-hunt population has varied from around 90 to 200 animals and the population has sustained an annual harvest of from 4 to 35 animals with primarily bucks-only hunting (Table 2).

The BLM's management objective for pronghorn antelope in the area is:

> "Improve or maintain about 40,000 acres of yearlong prognhorn range to allow for an increase in the WHA pronghorn population from the present 100 - 125 to 150 in five years." (Prichard et al. 1977.)

c. Mule Deer

When Capt. Gunnison traveled up Saguache Creek in 1853, his geologist wrote:

> "The banks of Sahwatch Creek (sic) which irrigates the valley are overgrown by willows and cottonwood, and the deer hiding in the bushes are so numerous that sometimes the bucks ran between our wagons when they were stirred up." (Mumey 1955)

Little is known of the historical fluctuations in numbers of deer in the area. Statewide deer herds in Colorado were thought to be at a low point in about 1910 (Anon 1950). However, Cary (1911) noted that:

> "Deer were reported as more abundant than usual on the mountains bordering the San Luis and upper Arkansas Valleys, and nearly all the hunters outfitting at Buena Vista, Salida, and Saguache during the open season of 1907 met with success."

Cary (1911) further attributes the subsequent decline to overhunting:

> "The Colorado game law in force during 1907 and 1908 allowed the killing of one deer 'with or without horns' by any person during the open season. This inclusion of deer without horns worked incalculable injury to the deer of Colorado during the two years it was operative, as a great many does and fawns were killed by unscrupulous hunters and particularly by novices. The pernicious results were not fully manifest in 1908, when it was estimated a total of about 2,500 deer were killed during the open season, but reports show that a great scarcity of deer throughout the mountains marked the season of 1909."

Hunting of deer was first restricted in Colorado with a closed season in 1912, and in 1914 it was estimated that not more than 12,000 were present in the entire state (McIntire 1942). From 1910 to 1929, deer herds showed a substantial increase (Anon 1950). By 1940, herds had recovered to the point where either-sex hunting was recommended and since then, either-sex hunting of deer has been practiced in Colorado.

Population estimates of the Colorado Division of Wildlife for Deer Units 68 and 681 which include the Trickle Mountain area indicate that numbers of deer were reasonably stable from 1963 to 1978 although substantial decreases occurred from 1978 to 1979, presumably due to the severe winters during those years (Table 3). However, some observers feel that deer numbers in the Trickle Mountain area have decreased substantially since the early 1960's (Hansen 1977) and statistics on harvest and hunter success (Table 4) support this contention, since both have dropped substantially.

Table 3. Estimated numbers and harvest of mule deer, Units 68 and 681, Saguache County, Colorado (from Olterman 1980).

Year	Population Size	Harvest
1963	3,869	491
1964	3,971	504
1965	3,849	728
1966	3,458	910
1967	3,687	300
1968	3,981	331
1969	3,876	662
1970	3,895	566
1971	4,201	345
1972	3,673	826
1973	2,830	705
1974	3,180	369
1975	3,603	234
1976	4,112	231
1977	4,444	431
1978	4,348	687
1979	3,738	252

Table 4. Estimated harvest and hunter success for mule deer, Game Management Unit 68, Saguache County, Colrado (from Prichard et al. 1977).

Year	Total Harvest	Number of Hunters	Percent Success
1969	662	1,147	58
1970	566	1,515	37
1971	337	843	40
1972	815	1,933	42
1973	693	2,611	27
1974	363	1,574	23
1975	230	2,253	10
1976	214	1,147	19

The BLM has estimated that there are 500 mule deer wintering on the Trickle Mountain area (Prichard et al. 1977). The BLM's management objective for mule deer in the area is to:

> "Improve habitat conditions on 20,000 acres of crucial mule deer winter range and 60,000 acres of year-long range to allow for an increase in the deer population from the present maximum of 500 to a maximum of 750 in five years." (Prichard et al. 1977.)

d. Elk

Elk were once numerous in the San Luis Valley but the combination of hunting and settlement resulted in extirpation by 1900 (Swift 1945). By 1912, there were not more than a few hundred elk in the state (McIntire 1942). In response to this decline, a closed season for elk was first established in Colorado in 1913. One of the remnant herds occupied the Saguache Creek drainage. From an estimated 25 elk in 1905, this herd increased to approximately 1,500 in 1940 (Swift 1945). Elk populations in other parts of the state were reestablished with transplants from 1912 to 1928 and this, combined with protection from hunting, allowed the herds to increase to the point where hunting was once again allowed in 1929 (Anon 1950). Since 1940, elk harvest has been on an either-sex basis (Anon 1950).

Data on estimated numbers (Table 5) and harvest (Table 6) from Game Management Unit 681 which includes the Trickle Mountain area indicate that both numbers of elk and harvest have been increasing.

The percentage of the elk in Unit 681 that occupy the Trickle Mountain area is not known. However, the BLM has estimated that 500 elk occupy the area in winter (Prichard et al. 1977). Olterman (1980) indicated that there is much ingress and egress of elk from the Trickle Mountain study area. Movement patterns of elk in this region are not well known. The management goal of the BLM for the area is "to maintain reasonable numbers of elk at about 500 head." (Prichard et al. 1977.)

H. History and Land Use

The town of Saguache is 1 of the oldest settlements in the San Luis Valley and was an established settlement when the first military expeditions from the U.S. traveled through the region in the 1850's.

Grazing in the Trickle Mountain area presumably followed the pattern for the San Luis Valley. The following description of livestock grazing in the area is from the U.S. Bureau of Land Management (1978a).

Table 5. Estimated numbers and harvest of elk, Game Management Units 68 and 681, Saguache County, Colorado.

Year	Number	Harvest	Source
1905	25	--	Swift (1945)
1945	1,500	--	Swift (1945)
1963	1,273	215	Olterman (1980)
1964	1,290	258	Olterman (1980)
1965	1,332	265	Olterman (1980)
1966	1,393	240	Olterman (1980)
1967	1,469	221	Olterman (1980)
1968	1,612	182	Olterman (1980)
1969	1,630	317	Olterman (1980)
1970	1,667	301	Olterman (1980)
1971	1,869	165	Olterman (1980)
1972	1,824	432	Olterman (1980)
1973	1,917	323	Olterman (1980)
1974	2,003	375	Olterman (1980)
1975	2,033	460	Olterman (1980)
1976	2,151	388	Olterman (1980)
1977	2,338	348	Olterman (1980)
1978	2,291	589	Olterman (1980)
1979	2,168	428	Olterman (1980)

Table 6. Estimated harvest and hunter success for elk, Game Management Units 68 and 681, Saguache County, Colorado (from Prichard et al. 1977).

Year	Total Harvest	Number of Hunters	Percent Success
1969	317	861	37
1970	301	1,293	23
1971	165	1,074	15
1972	432	2,083	21
1973	317	3,204	10
1974	375	3,799	10
1975	460	3,611	13
1976	384	3,228	12

"After years of summer grazing by small flocks of sheep in the early 1800s, permanent livestock production was established in the San Luis Valley in about 1842. Settlement and ranching expanded rapidly in the second half of the 19th century, with sheep use predominant in the lower half of the valley and cattle and sheep grazing about equal in the upper or northern part of the valley.

"Experiencing severe winter losses, most ranchers developed the use pattern that exists today: moving livestock from lower private lands in late spring to higher public lands (BLM and National Forest lands) for the summer, then moving the livestock onto BLM lands in the late summer and fall, and subsequently back onto private lands before winter to utilize regrowth on hay fields and hay as the primary sources of roughage (forage).

"During the early 1900s, drought and overgrazing combined with a lack-of-use regulations or supervision caused the condition of the range to decline. Following the enactment of the Taylor Grazing Act in 1934, the Grazing Service, with the help of district advisory boards, made specific allocations of public range to local livestock operators.

"In 1941, Grazing District #8 was established to administer domestic livestock grazing on public domain in the San Luis Valley. During the period from 1941 to 1943, range adjudication work--the apportionment of grazing use on public range among eligible applicants--was accomplished. Individual or common allotments were established.

"For the most part, the allowable use rates were excessive and the ranges continued to deteriorate. During the following several years the Grazing Service and later the BLM mainly issued licenses and permits and solved allotment boundary problems. Some downward adjustments in grazing use were made, however, on very critical areas and on areas where the operators cooperated.

"In the mid-1950s, the need for more appropriate stocking rates for individual allotments became obvious. As a result, range surveys were initiated on several grazing units in order to determine proper stocking rates for the various allotments. After these surveys were completed, stocking rates were reduced on most allotments. Many of these reductions were fairly drastic, ranging from 50 to 60 percent. Surveys continued intermittently through 1963, and reductions continued to be imposed. In the early 1960s some of the original surveys were rechecked, often resulting in additional reductions."

There are 7 BLM-administered grazing allotments within the Trickle Mountain area (Fig 4). All are grazed by cattle and 1 is also grazed by horses. Vecchia (1973) had indicated that accurate grazing records for the Trickle Mountain area are only available since 1961. Prior to 1950, there was considerable domestic sheep use with cattle use. Since then, there has been little or no use by domestic sheep. From about 1950 to 1961 the use was by cattle, but was heavier than in recent years. About 1961, some allotments were reduced 30 percent.

Other land uses in the area include limited timber harvest, mining, and recreational hunting and fishing.

I. Previous Studies

A number of studies have been conducted in the area.

Due to the high mineralization of the area, and use of the area as a training camp by students from the Colorado School of Mines, the geology of the area has been extensively studied. Bruns et al. (1971) described the local stratigraphy and refers to other studies of the geology of the area.

A soil survey has been conducted in the area by the U.S. Soil Conservation Service but has not been published.

Vegetation of the recognized bighorn sheep range of Trickle Mountain was described and compared to vegetation of the Buffalo Peaks area by Shepherd (1975). Shepherd compared the vegetation, climate, topography and grazing history of Trickle Mountain and Buffalo Peaks. The former is productive of bighorn sheep whereas the latter has been unproductive. He concluded that the climate, topography and vegetation of the Trickle Mountain habitat appeared to be more favorable for bighorn sheep. Both areas had a long history of heavy to severe use by cattle and domestic sheep but contemporary use (cattle) was heavier on the Trickle Mountain range.

Hassell et al. (1979) evaluated plant species and seeding methods for use on depleted rangeland and shallow soils at high elevations. The study was conducted in the center of the Trickle Mountain area on a BLM allotment. In 1972, an exclosure was constructed and various combinations of plant varieties and seeding methods were used within the exclosure. The seeding was subjectively evaluated each year from 1973 to 1978. Species and methods that responded well were: (1) wheatgrasses - disked-drilling or pitting broadcast method, (2) big bluegrass, Arizona fescue and sheep fescue - pitting broadcast method, and (3) Indian ricegrass - disked-drilling method.

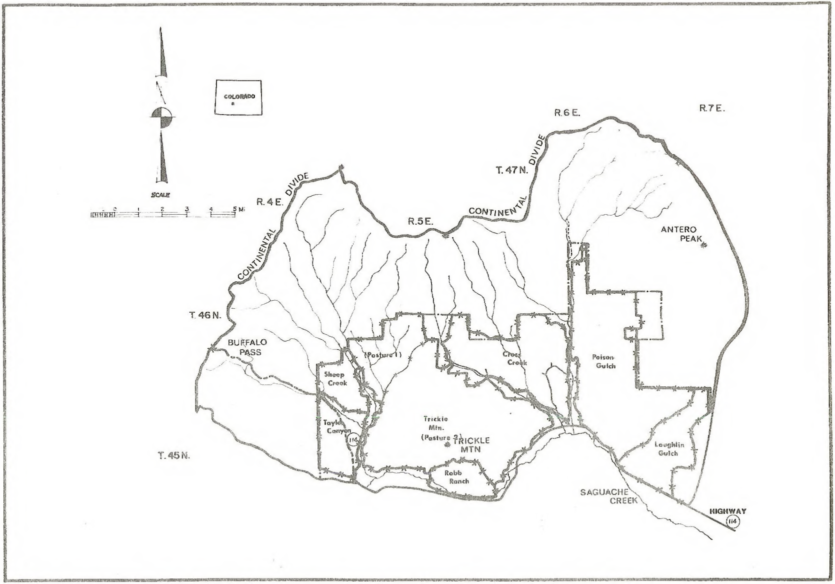

Figure 4. Grazing allotments administered by the BLM within the Trickle Mountain Study Area.

Food habits of bighorn sheep and pronghorn antelope have been studied in the area. Moser (1955) reported analyses of rumen contents from 2 bighorn harvested on Antero Peak in September. Bear and Jones (1973) indicated that sheep on Antero Mountain are from the Trickle Mountain herd. The Antero Mountain that he describes corresponds to what is now labeled as Antero Peak on USGS maps (Bonanza, Colo. 15' Quad, 1959) but as Antora Peak on BLM and U.S. Forest Service maps. This could lead to misunderstanding since there is another Antero Mountain approximately 50 km to the north in the Sawatch range.

Todd (1972a, 1975) reported seasonal food habits of bighorn sheep from Trickle Mountain based on the fecal analysis technique developed for analyzing sheep food habits (Todd and Hansen 1973; Hansen 1971).

Bear et al. (1973) reported on vegetative composition and food habits of pronghorn antelope from rabbitbrush types in Saguache County. The specific localities were not described, but it is possible that some or all of the data were collected from areas within or adjacent to the Trickle Mountain area.

From 1975 to 1979 a series of administrative reports were prepared by the BLM. These include a Habitat Management Plan (HMP), Allotment Management Plans (AMP's) for each of the 7 allotments in the area, and Draft and Final Environmental Statements (ES's) for San Luis Resource Area Grazing Management. These documents describe the land management objectives of the BLM for the area with respect to wildlife and livestock management and the potential impacts of alternative management systems on these and other resources.

Child (1979) used data from the ES on the Trickle Mountain and other allotments to analyze potential benefits to ranchers of increasing forage quality and quantity on BLM allotments.

III. FOOD HABITS

A. Methods and Materials

Microscopic analysis of cutinized plant epidermal fragments and lignified cell walls was used to determine diets of all ungulates present on the range. Ten fresh fecal samples, representing different animals were collected at 2-week intervals from the 4 wild ungulates during January 1978 through June 1979. In addition, 15 fecal samples were collected from each species of domestic ungulate for each 2-week period from each allotment whenever livestock were on the range. Because fecal samples of bighorn sheep, pronghorn antelope, and mule deer could not be consistently distinguished, animals were observed in the field prior to making collections. A total of 2955 samples (1560 from wild ungulates, 1155 from cattle, and 240 from horses) was collected. These were preserved in salt and sent to the Composition Analysis Laboratory at Colorado State University for analysis.

The botanical composition was estimated for each defecation using a microhistological technique (Ward 1970; Free et al. 1970). Fecal samples were ground over a 2mm screen and plant fragments were washed and collected over a 0.1 mm screen. Plant residues from the fecal samples were prepared on microscope slides and analyzed according to the procedure described by Sparks and Malechek (1968). One microscope slide was made from each defecation and the plant fragments occurring in 20 separate microscope fields viewed at 100X were quantified. Because no samples were composited, results from each slide represent an estimate of the diet of 1 animal during the given collection period.

For each ungulate species, results of each defecation were averaged to obtain a diet for each 2-week period. Diets were also summarized by season and year. For the livestock species data were summarized by allotment.

B. Results

1. Horses

Grazing by domestic horses is authorized only on the Poison Gulch allotment. Data for 2-week periods indicate that diets were reasonably consistent over the entire grazing season each year (Fig. 5). There was a slight but consistent tendency for browse to increase as the season progressed. Diets of horses during both years were dominated by 2 genera of grasses--grama and muhlys, and 1 browse species--winterfat (Table 7).

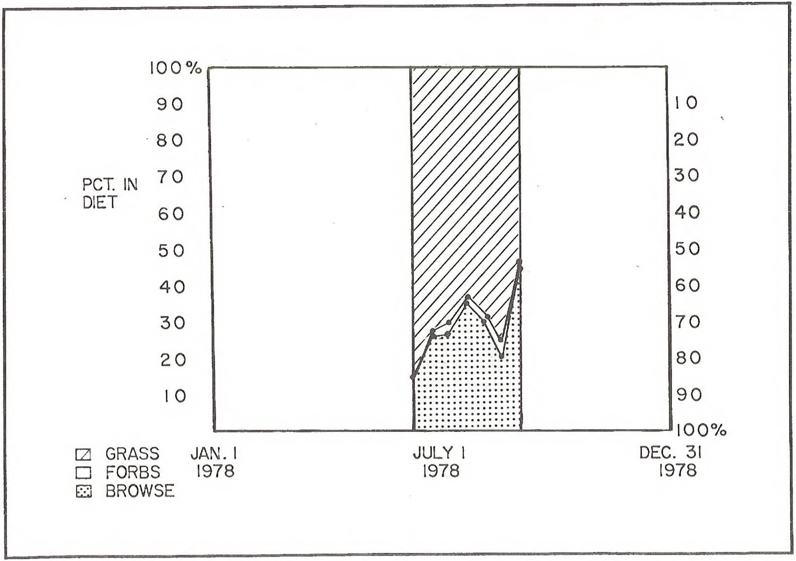

Figure 5. Estimated food habits of domestic horses, Trickle, Mountain, Colorado.

Table 7. Major forages in diets of domestic horses during 1978 and 1979 on Poison Gulch Allotment, Trickle Mountain, Colorado, as estimated by fecal analysis.

	Food Habits (%) [1,2]		
	Jun.-Sept. 1978	May-Oct. 1979	2-yr. Mean
Sample Size (defecations)	105	135	240
Grass and Grasslike Plants	71	62	62
Wheatgrass (*Agropyron* sp.)	5	4	4
Muhly (*Muhlenbergia* sp.)	30	3	17
Grama (*Bouteloua* sp.)	22	40	31
Sedge (Cyperaceae)	5	5	5
Other Grass & Grasslike Plants	9	10	10
Forbs	1	3	2
Browse	28	35	31
Winterfat (*Eurotia* sp.)	25	34	30
Other Browse	3	1	1

[1] Plants are listed by genera since the fecal analysis technique identifies plant fragments at the generic level.

[2] Only genera comprising at least 5% of either year's diet are listed.

2. Cattle

Cattle food habits by season for 1978 and 1979 and by allotment, for species comprising at least 5% of any seasonal diet (Tables 8 to 10) indicated that 6 grasses and grasslike forages--fescue, grama, muhlys, wheatgrass, sedges and rushes--comprised over 50% of any seasonal diet. Forbs and browse comprised smaller portions of the diet (Fig. 6); however forbs, especially goosefoot, were substantial components of some 1979 diets. The percentage of browses in the diet varied considerably among seasons, allotments and years.

Table 8. Major forages in diets of cattle on allotments within Trickle Mountain study area, spring 1978 and 1979, as estimated by fecal analysis.[1,2]

	Allotment									
	Laughlin Gulch		Poison Gulch		Cross Creek		Trickle Mountain		Taylor Canyon	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Grass and Grasslike Plants	81	69	83	72	83	63	87	79	72	49
Bluegrass (*Poa* sp.)	—	—	1	4	—	—	5	7	1	1
Dropseed (*Sporobolus* sp.)	13	13	1	—	4	3	—	—	—	—
Fescue (*Festuca* sp.)	—	—	3	6	2	—	17	7	17	4
Grama (*Bouteloua* sp.)	45	25	—	7	2	7	—	1	—	—
Muhly (*Muhlenbergia* sp.)	19	14	16	13	26	6	14	6	11	10
Needlegrass (*Stipa* sp.)	—	5	1	2	—	—	2	1	3	—
Rush (Juncaceae)	—	—	17	3	23	6	6	6	9	4
Sedge (Cyperaceae)	—	—	24	15	17	26	16	23	20	12
Squirreltail (*Sitanion* sp.)	1	3	1	7	—	1	3	6	2	6
Wheatgrass (*Agropyron* sp.)	1	3	14	12	7	6	21	18	7	7
Other Grass	2	6	5	3	2	8	3	4	2	7

Table 8. (Cont'd.)

	Allotment									
	Laughlin Gulch		Poison Gulch		Cross Creek		Trickle Mountain		Taylor Canyon	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Forbs	3	28	6	19	5	18	4	12	5	5
Globemallow (*Sphaeralcea* sp.)	--	23	--	6	--	2	--	--	--	--
Other Forbs	3	5	6	13	5	16	4	12	5	5
Browse	16	3	11	9	12	19	9	9	23	46
Sagebrush (*Artemisia* sp.)	--	--	--	--	--	--	2	1	7	3
Saltbush (*Atriplex* sp.)	5	--	--	--		3	--	--	--	--
Willow (*Salix* sp.)	3	--	4	4	2	--	4	1	7	3
Winterfat (*Eurotia* sp.)	6	3	--	--	5	15	-	4	6	37
Other Browse	2	--	7	5	5	1	3	3	3	3

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[1] Plants are listed by genera since the fecal analysis technique identifies plant fragments at the generic level.

[2] Only genera comprising at least 5% of either year's diet are listed.

Table 9. Major forage in diets of cattle on allotments within Trickle Mountain study area, summer 1978 and 1979, estimated by fecal analysis.[1,2]

	Allotment									
	Laughlin Gulch		Poison Gulch		Cross Creek		Trickle Mountain		Sheep Creek	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Grass and Grasslike Plants	72	64	84	76	80	32	78	54	96	54
Dropseed (*Sporobolus* sp.)	7	2	—	1	—	3	—	2	2	—
Fescue (*Festuca* sp.)	—	7	5	2	13	—	17	3	12	3
Grama (*Bouteloua* sp.)	24	6	4	10	2	20	3	15	—	1
Muhly (*Muhlenbergia* sp.)	35	24	13	4	23	—	28	10	5	1
Rush (Juncaceae)	—	—	21	7	7	1	3	—	50	14
Sedge (Cyperaceae)	—	9	18	21	10	1	8	10	22	14
Wheatgrass (*Agropyron* sp.)	1	8	11	10	11	3	12	4	3	11
Other Grass	5	8	12	21	14	4	7	10	2	10

Table 9. (Cont'd.)

	Allotment									
	Laughlin Gulch		Poison Gulch		Cross Creek		Trickle Mountain		Sheep Creek	
	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Forbs	5	24	6	20	4	56	7	33	3	38
Cinquefoil (*Potentilla* sp.)	--	1	2	6	--	--	3	11	2	10
Goosefoot (*Chenopodium* sp.)	--	9	--	3	--	52	--	12	--	27
Other Forbs	5	14	4	11	4	4	4	10	1	1
Browse	23	12	10	4	16	12	15	13	1	8
Sagebrush (*Artemisia* sp.)	1	2	1	--	3	--	11	--	--	--
Saltbush (*Atriplex* sp.)	13	--	0	--	4	--	--	--	--	--
Winterfat (*Eurotia* sp.)	5	1	2	--	6	11	--	4	--	--
Other Browse	4	9	7	4	3	1	4	9	1	8

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[1] Plants are listed by genera since the fecal analysis technique identifies plant fragments at the generic level.

[2] Only genera comprising at least 5% of either year's diet are listed.

Table 10. Major forages in diets of cattle on allotments within Trickle Mountain study area, fall 1978 and 1979, as estimated by fecal analysis.[1,2]

	Allotment						
	Laughlin Gulch		Poison Gulch	Cross Creek	Trickle Mountain	Sheep Creek	Robb Ranch
	1978	1979	1979	1979	1979	1978	1978
Grass and Grasslike Plants	70	46	51	54	50	93	85
Dropseed (*Sporobolus* sp.)	9	1	2	--	--	1	2
Fescue (*Festuca* sp.)	4	2	2	1	8	3	--
Grama (*Bouteloua* sp.)	32	26	15	39	3	3	4
Muhly (*Muhlenbergia* sp.)	17	1	1	3	14	9	10
Rush (Juncaceae)	--		10	--	1	45	27
Sedge (Cyperaceae)	1	2	9	4	11	17	30
Wheatgrass (*Agropyron* sp.)	6	8	5	7	5	10	5
Other Grass	1	6	7	--	8	5	7

Table 10. (Cont'd.)

	Allotment						
	Laughlin Gulch		Poison Gulch	Cross Creek	Trickle Mountain	Sheep Creek	Robb Ranch
	1978	1979	1979	1979	1979	1978	1978
Forbs	3	12	9	31	35	3	1
Cinquefoil (*Potentilla* sp.)		0	--	--	12	--	--
Goosefoot (*Chenopodium* sp.)		6	--	22	13	--	--
Other Forbs	3	6	9	9	10	3	--
Browse	26	52	40	15	15	4	14
Mountainmohagany (*Cercocarpus* sp.)	--	--	34	--	--	--	--
Sagebrush (*Artemisia* sp.)	--	--	--	1	4	2	--
Saltbush (*Atriplex* sp.)	18	--	--	--	--	1	13
Winterfat (*Eurotia* sp.)	5	45	4	13	6	--	--
Other Browse	3	7	2	1	5	1	1

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[1] Plants are listed by genera since the fecal analysis technique identifies plant fragments at the generic level.

[2] Only genera comprising at least 5% of either year's diet are listed.

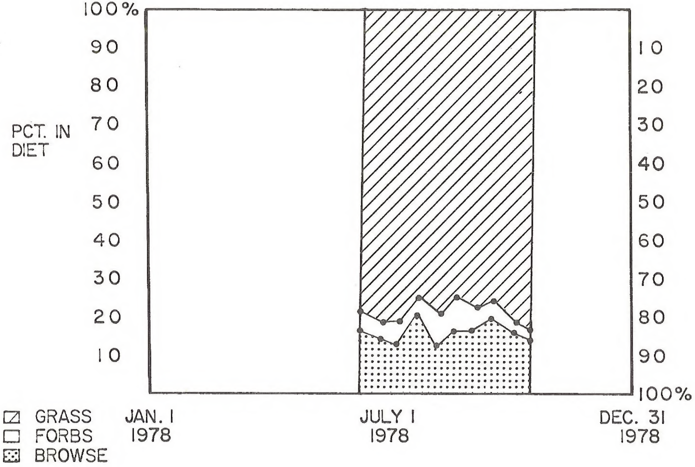

Figure 6. Estimated food habits of cattle, Trickle Mountain, Colorado.

3. Bighorn Sheep

A total of 74 genera (22 grasses, 31 forbs, and 21 browses) were identified in the feces of bighorn sheep, but only 10 contributed over 5% to any seasonal diet (Table 11). Browses, particularly sagebrush, constitued a major portion of the diet during all seasons (Fig. 7), although grasses were used substantially more during the winter of 1979 than in the previous winter. Forbs constituted less than 15% of the diet during each season.

4. Pronghorn Antelope

A total of 77 genera (19 grasses, 32 forbs, and 26 browses) were identified in the feces of pronghorn antelope, but only 9 contributed over 5% to any seasonal diet (Table 12). Browses, particularly sagebrush and rabbitbrush, constituted major portions of the diet during all seasons (Fig. 8). Grasses comprised less than 10% of the diet during each season.

5. Mule Deer

A total of 83 genera (21 grasses, 36 forbs and 26 browses) were identified in the diets of mule deer, 13 contributing over 5% to at least 1 seasonal diet (Table 13). Browses were the most abundant forage class in the diet, comprising over 75% of the diet in each season (Fig. 9). Willow was the most abundant forage during summer, comprising 75% of the estimated diet. The conifers (pine, Douglas fir, and juniper) comprised a sustantial portion of the diet in the winters of 1978 and 1979 (26% and 40% respectively). Sagebrush constituted 36% of the winter diet in 1978 but only 8% in 1979.

6. Elk

A total of 77 genera (24 grasses, 29 forbs, and 24 browses) were identified in the diets of elk and 17 genera comprised at least 5% of one or more seasonal diets (Table 14). Grasses comprised over 40% of the estimated diet during all seasons with the exception of the winter of 1978 when grasses comprised only 24% of the diet (Fig. 10). Browse was the most important forage class in the diet in fall and winter, comprising over 50% of the estimated diet in fall 1978 and in the winters of 1978 and 1979. Sagebrush was the most abundant genus in the estimated diet for the winter of 1978, but dropped to only 5% for the winter of 1979. Forbs comprised less than 20% of the diet during all seasons except summer.

Table 11. Major forages in diets of bighorn sheep on Trickle Mountain study area, 1978-1979, as estimated by fecal analysis.[1,2]

	Season											
	Winter 1978		Winter 1979		Spring 1978		Spring 1979		Summer 1978		Fall 1978	
	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE
Grass and Grasslike Plants	22		52		52		53		39		36	
Dropseed (*Sporobolus* sp.)	1	0.5	6	0.9	1	0.5	3	0.7	1	0.2		
Fescue (*Festuca* sp.)	5	0.7	1	0.4	11	0.8	5	0.8	4	0.7	6	0.9
Grama (*Bouteloua* sp.)	2	0.5	18	1.9	2	0.3	7	1.0	5	1.4	6	0.6
Muhly (*Muhlenbergia* sp.)	7	1.4	14	1.3	16	1.8	8	1.2	10	1.7	9	1.1
Sedge (*Cyperaceae*)	2	0.3	3	0.7	8	2.3	17	1.9	9	1.6	3	0.7
Other Grasses	5		10		14		13		10		12	
Forbs	2		3		7		14		13		3	
Browse	76		45		41		33		48		61	
Mountainmahogany (*Cercocarpus* sp.)	tr		tr		4	1.0	2	1.5	19	2.9	2	0.6
Sagebrush (*Artemisia* sp.)	55	2.8	14	2.2	22	0.7	7	1.0	4	0.8	20	2.3
Saltbush (*Atriplex* sp.)	8	1.2	9	1.0	1		3	0.7	7	2.2	28	2.2
Winterfat (*Eurotia* sp.)	4	1.0	9	1.8	2	0.6	8	1.6	4	1.3	6	1.2
Yucca (*Yucca* sp.)	5	0.6	8	0.8	1	0.2	2	0.5	1	0.3	2	0.4
Other Browse	13		5		11		11		13		3	
Sample size	60		60		70		70		60		70	

[1] Major forages are those genera or plant groups that comprise at least 4.5% of at least one seasonal diet.

[2] SE = Standard error of the mean; tr = <0.5%

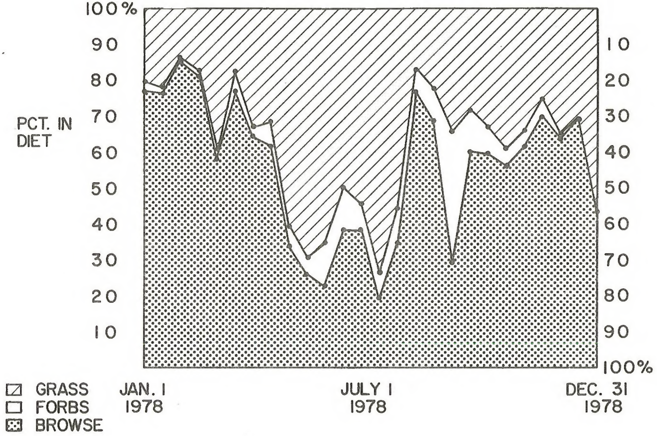

Figure 7. Estimated food habits of bighorn sheep, Trickle Mountain, Colorado.

Table 12. Major forages in diets of pronghorn antelope on Trickle Mountain study area, 1978-1979 as estimated by fecal analysis.[1,2]

	Season											
	Winter 1978		Winter 1979		Spring 1978		Spring 1979		Summer 1978		Fall 1978	
	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE
Grass and Grasslike Plants	3		2		6		3		3		2	
Forbs	2		6		20		29		34		12	
Cinquefoil (*Potentilla* sp.)					5	0.6	6	1.2	11	1.1	4	1.4
Eriogonum (*Eriogonum* sp.)					1	0.6			9	1.3		
Other Forbs	2		6		14		23		14		8	
Browse	95		92		74		69		63		86	
Cactus (Cactaceae)	1	1.5	11	1.0	2	1.9	10	4.3			1	0.2
Currant (*Ribes* sp.)					8	1.1	2	1.0	2	0.5		
Mountainmahogany (*Cercocarpus* sp.)					2	0.5	1	0.5	20	2.1	1	0.5
Rabbitbrush (*Chrysothamnus* sp.)	19	1.7	34	4.4	7	1.0	9	1.4	9	1.4	37	2.1
Sagebrush (*Artemisia* sp.)	68	2.1	34	3.4	43	2.9	27	2.8	26	2.1	24	2.4
Saltbush (*Atriplex* sp.)	6	1.0	10	1.2	4	5.8	8	1.6			18	3.3
Winterfat (*Eurotia* sp.)			1	0.3	1	1.3	5	3.9				
Other Browse	1		2		7		7		6		5	

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[1] Major forages are those genera or plant groups that comprise at least 4.5% of at least one seasonal diet.

[2] SE = Standard error of the mean; tr = <0.5%

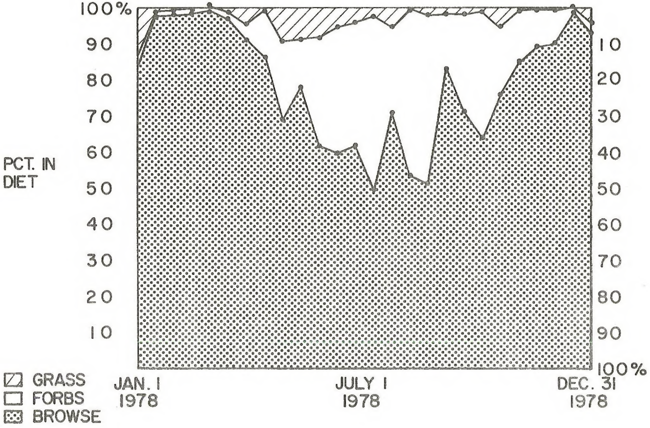

Figure 8. Estimated food habits of pronghorn antelope, Trickle Mountain, Colorado.

Table 13. Major forages in diets of mule deer on Trickle Mountain study area, 1978-1979 as estimated by fecal analysis.[1,2]

	Season											
	Winter 1978		Winter 1979		Spring 1978		Spring 1979		Summer 1978		Fall 1978	
	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE
Grass and Grasslike Plants	5		10		16		7		1		4	
Forbs	5		5		8		16		8		20	
Cinquefoil (*Potentilla* sp.)			1	1.7	1	0.3	2	0.7	2	0.4	6	2.0
Lupine (*Lupinus* sp.)											7	3.6
Other Forbs	5		4		7		14		6		7	
Browse	90		85		76		77		91		76	
Cactus (Cactaceae)			3	0.5			5	1.7				
Currant (*Ribes* sp.)	1	0.3			9	1.8	2	1.0	2	0.7	1	0.3
Douglas fir (*Pseudotsuga* sp.)	7	1.8	7	2.0	3	0.8	3	0.9			7	1.3
Juniper (*Juniperus* sp.)	12	1.2	9	1.4	5	0.9	9	1.4			10	2.2
Mountainmahogany (*Cercocarpus* sp.)	2	0.7	1	0.8	6	2.1	1	1.0	3	0.7	5	1.2
Pine (*Pinus* sp.)	7	1.3	24	2.9	5	2.4	5	1.3			4	1.1
Rabbitbrush (*Chrysothamnus* sp.)	4	0.7	8	1.0	1	0.5	3	1.5			11	2.1
Rose (*Rosa* sp.)					2	2.8			7	1.2	2	0.7
Sagebrush (*Artemisia* sp.)	36	3.3	8	1.8	30	3.4	24	3.0			11	1.5
Saltbush (*Atriplex* sp.)	13	1.5	13	1.9			5	0.8			10	2.7
Willow (*Salix* sp.)	5	2.8	2	0.7	10	6.8	13	2.3	75	2.4	6	4.5
Other Browse	3		10		5		7		4		9	

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[1] Major forages are those genera or plant groups that comprise at least 4.5% of at least one seasonal diet.

[2] SE = Standard error of the mean; tr = <0.5%.

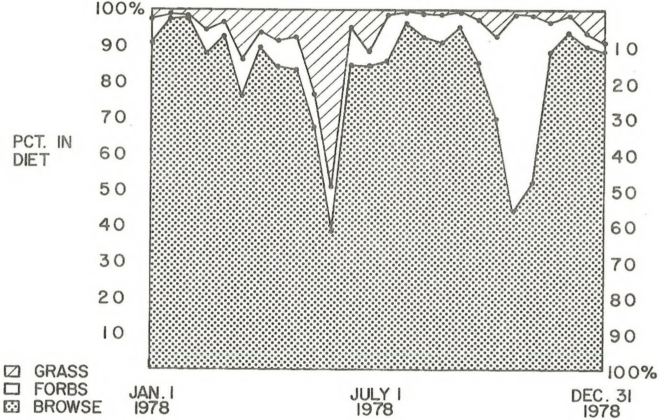

Figure 9. Estimated food habits of mule deer, Trickle Mountain, Colorado.

Table 14. Major forages in diets of elk on Trickle Mountain study area, 1978-1979 as estimated by fecal analysis.[1,2]

	Season											
	Winter 1978		Winter 1979		Spring 1978		Spring 1979		Summer 1978		Fall 1978	
	%	SE	%	SE	%	SE	%	SE	%	SE	%	SE
Grass and Grasslike Plants	24		47		62		47		46		40	
Bluegrass (*Poa* sp.)	2	0.4	2	0.8	7	0.8	3	0.5	4	0.6	6	0.8
Dropseed (*Sporobolus* sp.)	1	0.3	6	1.1							1	0.3
Fescue (*Festuca* sp.)	7	1.1	9	1.3	16	1.2	8	1.1	12	1.3	6	1.1
Muhly (*Muhlenbergia* sp.)	3	0.4	12	1.4	8	0.9	4	1.2	2	0.4	4	0.6
Needlegrass (*Stipa* sp.)					3	0.5	1	0.4	1	0.3	6	0.9
Oatgrass (*Danthonia* sp.)					5	1.8			4	0.9	1	0.5
Sedge (Cyperaceae)	2	0.3	2	1.8	9	1.8	13	1.7	15	1.5	8	1.7
Wheatgrass (*Agropyron* sp.)	2	0.5	2	0.5	5	0.7	9	1.1	4	0.8	6	0.8
Other Grasses	7		14		9		9		4		2	
Forbs	2		2		8		12		27		9	
Cinquefoil (*Potentilla* sp.)			1	3.4	3	0.6	4	1.3	9	0.7	3	0.6
Eriogonum (*Eriogonum* sp.)									7	1.0		
Other Forbs	2		1		5		8		11		6	
Browse	74		51		30		41		27		51	
Buffaloberry (*Shepherdia* sp.)									9	1.8	4	2.4
Douglas fir (*Pseudotsuga* sp.)	8	0.8	10	1.9	1	0.3	2	0.4			1	0.6
Rabbitbrush (*Chrysothamnus* sp.)	4	0.6	3	0.5	1	0.4	1	0.9	2	0.4	7	1.7
Sagebrush (*Artemisia* sp.)	48	3.0	5	0.8	14	2.4	21	2.6	5	0.8	7	0.9
Saltbush (*Atriplex* sp.)	2	0.6	4	0.9			1	0.4			6	1.6
Winterfat (*Eurotia* sp.)	2	0.7	1	0.5			1	1.0	1	0.3	12	3.2
Yucca (*Yucca* sp.)	5	0.7	23	1.9	1	0.5	2	0.7			5	1.6
Other Browse	5		5		13		13		11		9	

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[1] Major forages are those genera or plant groups that comprise at least 4.5% of at least one seasonal diet.

[2] SE = Standard error of the mean; tr = <0.5%.

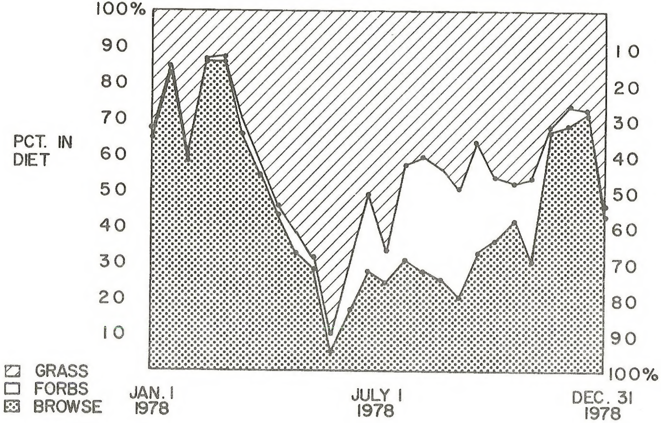

Figure 10. Estimated food habits of elk, Trickle Mountain, Colorado.

C. Discussion

1. Horses

Horses are commonly assumed to be primarily grazers or grass-eating animals (Hafez et al. 1969; Stoddart et al. 1975), yet there are suprisingly few studies of food habits of either feral or domestic horses. Skiles et al. (1980a), in a review of the botanical compositions of ungulate diets in western North America, reported only 6 references on food habits of horses. All were studies of feral horses and only 1 (Hansen 1976) reported consumption of browse in excess of 5%. Results from this study generally support the assumption that horses are primarily grass eaters, at least during the late spring to early fall season.

Horse consumption of gramagrass increased in 1979, compared to 1978 (Table 7). Late spring of 1979 was warmer and wetter than 1978, creating favorable conditions for growth of blue grama. The increased use of gramagrass may partially account for the noticeable decrease in muhlys in the 1979 diet. The grasses--blue grama, mountain muhly and slimstem muhly--are among the most abundant species on the range (Table 18, Section VI) and are considered highly palatable and nutritious for livestock.

Winterfat was the only significant non-grass species in the horse diet. Winterfat is not particularly common on most of the range and comprises less than 1% of the estimated plant composition. This suggests winterfat is highly preferred by horses. Within the Poison Gulch allotment are small sites with limey soils on benches and fans above riparian areas on which winterfat produces up to 25kg/ha and comprises over 50% of the annual forage production. Horses were often observed on these areas and thus the high proportion of winterfat in the diet may be due partly to a preference for such sites.

Winterfat is considered a valuable forage species for both livestock and wildlife in the western United States (Dayton 1937; Stevens et al. 1977). Cotton (1904) referred to the particular value of this species for horses. However, winterfat is considered very sensitive to grazing. Stevens et al. (1977) indicated that removal of more than 25% during the growing season will deplete plant vigor.

The apparent preference of horses for winterfat and/or winterfat sites, the sensitivity of the plant to grazing during the growing season, and the value of winterfat to wild ungulates suggest that stocking rates for horses on winterfat ranges should be conservative during spring and summer.

2. Cattle

Cattle food habits were influenced by seasonal variation in habitat selection, by distribution of forage species, by between-years variation in forage production (primarily of forbs), and by cattle forage preferences.

The most abundant grass species within the Trickle Mountain area were also the major species in the seasonal cattle diets. Furthermore, the percentage of each grass species in the diet was highly correlated with the percentage of the species on each allotment (Table 18, Section VI). Overall, grasses were most preferred and constituted over 50% of most seasonal diets. However, use of forbs and browse was highly variable, probably resulting from great variation in palatability and production. Browse species that were consistently selected (found in a higher percentage in the diet than on the range) were saltbush and winterfat.

Seasonal variation in cattle forage selection was illustrated by amounts of bluegrass in the diets. Bluegrass exceeded 5% of the diet only in spring. This may have been due to high preference for the species at this season, to depletion of the small amount of bluegrass on the range, or both.

Effects of year-to-year variation in production were greatest for forbs. Forbs were noticeably more abundant on the range in 1979 as opposed to 1978. Estimates of forb abundance from identical transects observed in both years indicated over 100% increase in some forb species. The cattle diets reflected this shift in availability as forbs consistently comprised a higher percentage of the diets in 1979.

Habitat selection greatly influenced the cattle diet. Many apparent anomalies in diet variation can be qualitatively explained by knowing where the cattle spent most of their time and/or where fecal samples were collected. For example, the high percentage of rushes in the diet of Sheep Creek cattle (up to 50%, even though it only constituted 4% of the total vegetation) can be explained by their preference for foraging in riparian areas. Similarly, the high percentage of saltbush and winterfat in the diet of Laughlin Gulch cattle can be explained by their disproportionate use of the flat areas around a spring at the base of the mountains. These are the only areas where these browses are available in any abundance on the allotment. Obviously preference for certain habitat types may be strongly influenced by the presence of highly preferred forages so habitat and forage preferences cannot be completely separated.

3. Bighorn Sheep

The Artemisia species utilized abundantly by bighorns and the other wild ungulates at Trickle Mountain during winter and spring is primarily fringed sagebrush A. frigida since that is virtually the only sagebrush species available on the winter/spring range. High utilization and apparent preference for fringed sagebrush by both domestic and wild ungulates is common wherever the species is present (Cooperrider and Bailey 1981). With respect to wild sheep, Hoefs and Cowan (1979) state:

> "There are two aspects in which most researchers agree: grasses and grasslike vegetation appear to be the most important forage group for sheep in general, and wherever pasture sage (Artemisia frigida) is an important component in the vegetation cover of a sheep range, it is also an important forage species."

Similarly, the principal and the only perennial species of saltbush present at Trickle Mountain is four-wing saltbush, A. canescens, and this species is also recognized as being highly preferred by both big game and livestock (Plummer et al. 1966).

Heavy use of mountainmahogany by bighorn sheep in summer is less well documented, although several recent reports have indicated this pattern (Cooperrider 1982; Cooperrider and Hansen 1982; Haas 1979; Rominger and Bailey 1982). The species being utilized is true mountainmahogany (C. montanus) and observations of feeding sheep as well as reports of technicians reading slides of fecal material indicate that the animals are primarily eating leaves. Leaves of certain deciduous species are probably similar nutritionally to palatable forbs. Since the spring/summer lambing ranges have a limited quantity of palatable forbs and a relatively high concentration of mountainmahogany, the high utilization of this species is not surprising.

Bighorn utilization of and preference for grass species is an important consideration in sheep management. Todd (1972) in a review of bighorn sheep food habits stated, "Grasses and grasslike plants (Carex spp.) comprise staple forage for the Rocky Mountain and California bighorn subspecies." The question remains, "Do sheep prefer grass and grasslike plants, or do they utilize grass out of necessity because they have the physiological capability of surviving on such forage when better forages are unavailable?" A distinction needs to be made between green grass and dormant grass. The apparent preference for grass and grasslike species by bighorn during spring and summer probably represents a real preference for green grass. Dry (dormant) grass, however, is recognized as far less nutritious than green grass (Stoddart et al. 1975:233). The observed increased utilization of grass in the severe winter of 1979 coincident with decreased utilization of fringed sagebrush suggests that dry grasses are not preferred forages, but rather are less preferred forage that bighorns are adapted to utilizing when better forages are not available.

Moreover, the structure of grasslands favors the evolved predator evasion strategy of bighorn sheep (Risenhoover and Bailey 1980) and therefore favors an abundance of grasses in bighorn diets. Bighorns are adapted to foraging in a large group of dispersed animals. Such a group is especially aware of a great proportion of its surroundings. Predators are detected visually and alertness is communicated visually. When necessary, the group will flee to nearby escape terrain. This strategy requires that forage resources near escape terrain be abundant (to support a large group), continuous rather than patchy (to allow dispersion of sheep, minimizing competion and enhancing awareness of surroundings) and low growing (allowing for predator detection and visual communication). Thus, while bighorns are not obligatory grazers, Rocky Mountain bighorns are primarily grazers because stands of grasses and/or sedges most frequently and most prefectly provide low, abundant and continuous forage needed for the animal's predator evasion strategy.

4. Pronghorn Antelope

High utilization of and preference for shrubs such as sagebrush and saltbush and low utilization of grasses by Trickle Mountain pronghorn are consistent with food habits of the species in many areas (Sundstrom et al. 1973). Antelope are known to forage and survive on many species, such as rubber rabbitbrush and big sagebrush, that are relatively unpalatable to other ungulates. The increased utilization of cactus and rabbitbrush in the severe winter of 1979 suggests that these are non-preferred species that can provide emergency or short-term maintenance forage.

5. Mule Deer

Heavy use of browse by Trickle Mountain deer throughout the year, with limited use of green grass and forbs in spring, is again consistent with reported diets of the species (Kufeld et al. 1973).

The distinctively high percentage of willow reported for summer diets of deer is due to the location of fecal collections. Most deer fecal collections during summer were made along Saguache Creek which was the only readily accessible area where the density of deer was sufficient for collecting fecal samples. This area supports a high density of willow. Deer spend summer on other parts of the study area in low densities and food habits from these areas are likely much different.

The second most distinctive feature of the Trickle Mountain deer diet, compared to diets of other ungulates, was the heavy use of conifers. This probably reflects in part a preference for habitats with coniferous overstories. However, the other ungulates on Trickle Mountain made substantial use of conifer habitats but did not forage much on conifers. The increased use of conifers in winter and in the severe winter of 1979 compared to 1978 suggests that these are less preferred species to which deer may turn in times of limited forage.

6. Elk

Food habits of elk were the most variable among the ungulate species on Trickle Mountain. Both grass and browse was utilized in large quantities during various seasons. This is typical of elk food habits (Kufeld 1973).

The increased utilization of grasses and decreased use of species like sagebrush during the winter of 1979 suggests that elk were turning to dry grass out of necessity rather than preference. On the other hand, the high use of green grass in spring probably reflects a real preference.

D. Summary and Conclusions

Seasonal food habits of the ungulates on the Trickle Mountain study area were estimated using fecal analysis. Food habits of all 6 ungulates vary substantially among seasons and years. Furthermore, food habits of cattle vary considerably among allotments. However, food habits data presented here are generally consistent with patterns of food habits reported in the literature.

The reported seasonal, annual and local variation in ungulate food habits emphasizes the complexity of ungulate forage competition and the difficulty of forage allocation. Realistic forage allocation requires that species food habits be considered in a flexible allocation system that considers variable food habits. Such flexibility is provided by the forage allocation model described in Section VII of this report.

IV. HABITAT USE

Habitat use for all 4 wild ungulates on the Trickle Mountain study area was determined during 1978 and 1979. In addition cattle distribution was studied, primarily in areas of overlap with bighorn sheep. Cattle distribution is described in McCollough (1982).

A. Methods and Materials

1. Field Observation

Wild ungulates were observed from the ground on fixed routes through the area with binoculars and spotting scopes, several times during each 2-week period from January 4, 1978 through December 1, 1979. In addition, 3 fixed-wing flights were used in winter and spring. A total of 2884 observations of distinct groups of animals were recorded. For each observation, the date, time, route number, location (legal description), weather conditions (snow depth, temperature, wind speed, and cloud cover), and species were recorded. The activity (feeding, moving, bedded) was recorded and the sex and age of each animal was determined when possible.

2. Data Analysis

All data were coded and entered on computer files for analyses of correlations of animal distributions with habitat features and weather variables. Field observations and preliminary analyses of these data indicated that animal distribution could not be consistently predicted using such correlations and that observed distributions of animals by season were the most practical measures to incorporate into a forage allocation model.

Seasonal distributions were determined by plotting all observations on 7.5-minute topographic maps and using these plots to determine boundaries of seasonal ranges.

B. Results

1. Bighorn Sheep

Bighorn sheep concentrate in 2 distinct areas of the winter ranges separated by Jacks Creek (Fig. 11). Although there is undoubtedly some interchange between these areas, particularly of older rams, evidence from marked animals indicates that there is little or no exchange of lambs and ewes. There were approximately 20 lambs and ewes marked with ear tags and neck bands after being captured south of Trickle Mountain on the Robb Ranch allotment. None of these marked sheep were observed in the Middle Creek-Jacks Creek area during the study, although they were frequently observed in the vicinity of Trickle Mountain.

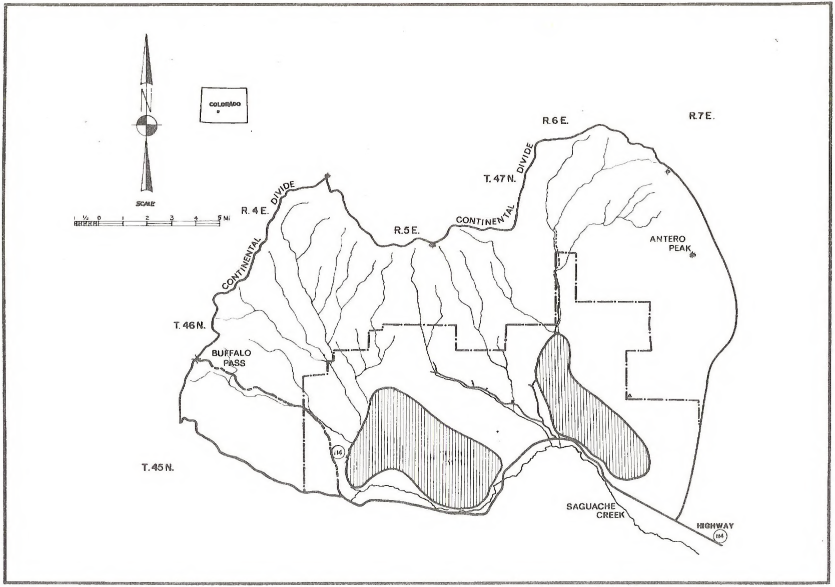

Figure 11. Winter concentration areas of bighorn sheep, Trickle Mountain, Colorado.

During spring ewes and young rams from Trickle Mountain move to a lambing area near Buffalo Pass, whereas lambs and ewes from Middle Creek stay in the same general area (Fig. 12). Some sheep move to the Antero Peak area although this area was not observed frequently. In fall sheep drift back from lambing areas to the winter ranges. Marked animals, previously seen on the Buffalo Rocks lambing area in spring, were observed back on the hayfields below Trickle Mountain by mid-July. Distribution of sheep during this season is quite diffuse.

2. Pronghorn Antelope

Pronghorn antelope were observed year-round in substantial numbers on their lower elevation winter range (Fig. 13). However, there was some expansion during spring and summer onto adjacent areas. During the winter and spring they were generally observed in open relatively snow-free areas, although they would make some use of the less dense pinyon-juniper stands.

In summer, antelope were frequently observed in the western portion of the study area west of Sheep Creek in small parks of from 2-10 ha (5-25 acres) that were surrounded by dense timber.

3. Mule Deer

Mule deer were on the lower elevation BLM lands primarily during late fall, winter, and spring (Fig. 14). During winter they were found throughout the low elevations except in areas without tree cover, such as Sheep and Antelope Creek, or in areas with snow over 30 cm (1 ft).

During spring many deer moved toward higher elevation summer ranges although a substantial number moved to the lower elevation, riparian areas along Saguache Creek which are primarily on private land. The summer distribution of deer at higher elevations was not well documented although a summer concentration of deer was noted in the Sargents Mesa area along the Continental Divide at the northern edge of the study area. Deer were noticeably scarce on the western portion of the study area (west of Sheep Creek) during spring and summer.

4. Elk

Elk were found on the lower elevation BLM lands primarily during winter and spring. During winter their distribution was similar to that of mule deer although they were not found as close to Highway 114 on the south edge of the study area (Fig. 15). Elk concentrated on the north side of Trickle Mountain during mid-winter and made considerable use of the grassland parks adjacent to heavier timber in that area.

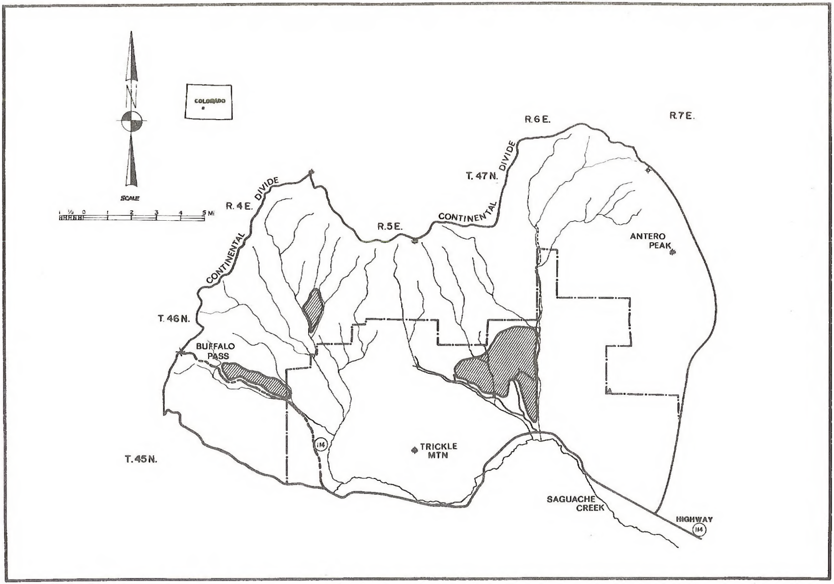

Figure 12. Lambing areas for bighorn sheep, Trickle Mountain, Colorado.

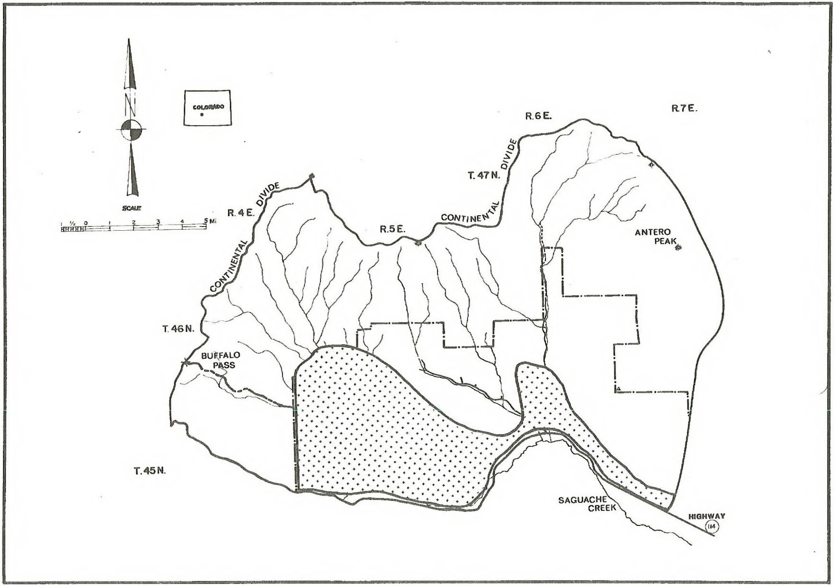

Figure 13. Year-round range of pronghorn antelope, Trickle Mountain, Colorado.

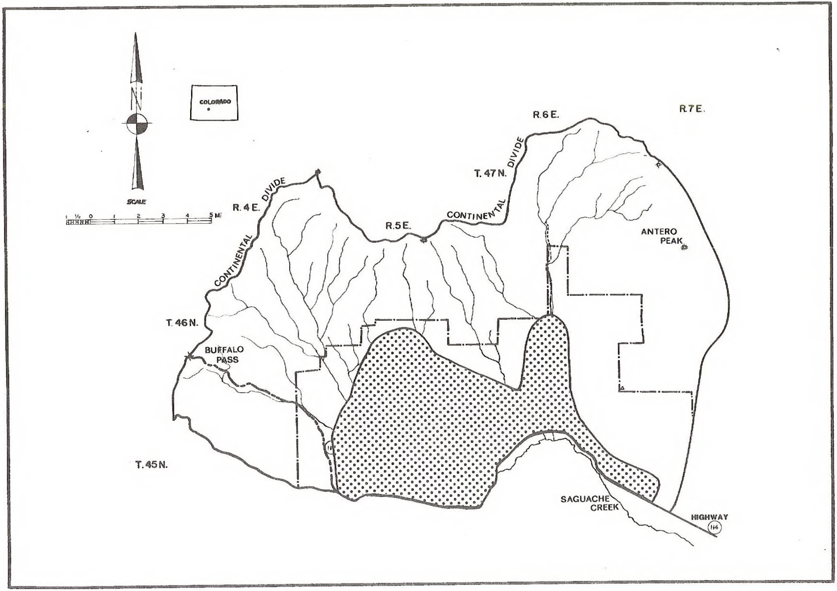

Figure 14. Winter range of mule deer, Trickle Mountain, Colorado.

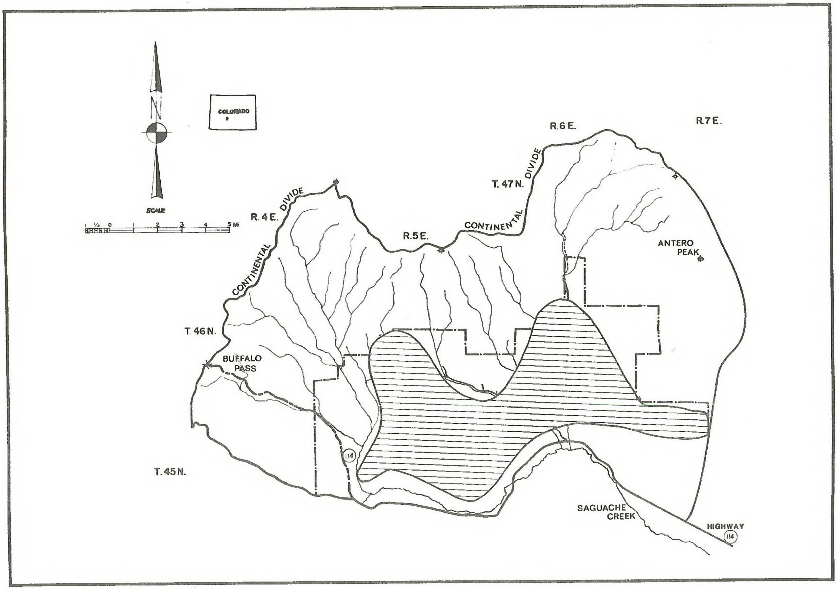

Figure 15. Winter range of elk, Trickle Mountain, Colorado.

In spring, elk moved from this center to the north and west, making considerable use of the North Park, upper Antelope Creek (Antelope Park), and Indian Park areas. The degree to which elk moved south across Highway 114 and out of the study area is not well known. Summer distribution of elk in the area is not well known although a concentration of elk was noted in the Sargents Mesa area in early July, prior to cattle being turned out in that area.

C. Discussion

The wild ungulates on Trickle Mountain generally occupy habitats typical of those reported for other populations of these species. However, in a few cases what would appear to be suitable or potential habitat is not used, and in 1 area pronghorn antelope occupy atypical habitat in spring-summer-fall. There was a great deal of overlap in range use, and groups of 2 or more ungulate species were frequently seen within 100 m of each other during the winter concentration period.

1. Bighorn Sheep

Bighorn sheep were found on or near open, rocky precipitous terrain at all times of year as is typical of mountain sheep (Geist 1971). Such escape terrain was the dominant factor influencing their distribution on the range. In winter, sheep were generally found in areas with less than 20 cm (8") of snow on the ground. In spring, expansion from concentration areas was probably correlated with diminishing snow cover.

The Middle Creek lambing area had not been reported prior to this study and may be a recent range extension since earlier workers did not note it (Bear and Jones 1973; Shepherd 1975; Todd 1978).

The 2 major lambing areas are different in vegetative cover. The Middle Creek area is primarily a shortgrass type dominated by blue grama whereas the Buffalo Rocks area, located approximately 750m (2400 ft) higher, is primarily a pine-bunchgrass type dominated by Arizona fescue. The common characteristic of both areas is the presence of very steep rocky slopes in close proximity to riparian areas with surface water. Sheep were observed to feed extensively in such riparian areas, but it is not known whether the presence of free water or of succulent riparian vegetation was a more important determinant in bighorn selection of such areas for lambing.

The distribution of bighorn sheep in fall appeared to be erratic and unpredictable. This was probably due to the extensive hunting seasons and associated disturbance. There were separate and combined seasons for deer and elk, seasons for pronghorn antelope, and bighorn sheep, and special muzzle-loading and archery seasons. There was 1 or more open seasons in the area continuously from late August through mid-November. Bighorn sheep and other ungulates were observed in areas they didn't normally occupy during this period.

The bighorn population of the study area is one of the largest and most productive in Colorado. Success of this herd depends upon the excellent quality of its habitat. There are many open areas with suitable escape terrain in proximity to abundant, continuous (not patchy) forage. The number and distribution of these areas allow Trickle Mountain bighorns frequent movements, including seasonal migrations. In contrast, many Colorado bighorn herds show a sedentariness that exacerbates many problems common to the state's herds, including lungworm infestation and an inability to excape from temporary human disturbance. Maintaining the quality of the Trickle Mountain bighorn herd will depend upon maintaining the integrity of many areas of suitable habitat and of migration routs between these areas. Major threats to this objective will be (1) any deterioration of forage condition due to overgrazing or perhaps to forest succession, (2) any human developments that could discourage use of seasonal ranges or migration routes, and (3) gradual forest succession that reduces visibility, an important characteristic of bighorn habitat (Risenhoover and Bailey 1980).

2. Pronghorn Antelope

The low-elevation habitats used by pronghorn antelope are typical of pronghorn habitat elsewhere, consisting of rolling, wide-open, expansive terrain with low vegetation that permits distant visibility and rapid mobility (Yoakum 1978).

Pronghorn use of small parks in forested areas on the west end of the study area is not typical, since visibility is impaired in such areas and the only escape routes are through timber with very low visibility. These parks probably produce good quality forage, however, since they are at higher elevations on sites that remain moist and produce succulent vegetation throughout the summer. This is in contrast to the rest of the range which often lacks such vegetation after midsummer. During the summer of 1979 when conditions were much wetter and the lower elevation ranges contained more succulent vegetation, pronghorns were not observed as frequently in the parks at higher elevations.

3. Mule Deer

Most of the BLM lands are suitable winter deer range, containing a diversity of habitat types and a high degree of interspersion of forest, shrub and grassland vegetation

(Wallmo 1979). Mule deer selection of winter and spring habitat appeared to be primarily influenced by the presence of preferred browse species and by snow cover. Areas with small patches of browse below rocky breaks or around the edges of stringers of timber were favored for feeding.

Deer use of the riparian areas in summer was probably due to the presence of dense stands of willow interspersed with grassland and hayfields. The willow thus provided good cover in addition to supplying over 70% of the deer diet in summer.

The lack of deer use in summer of the western portion of the study area, which appeared to be good summer deer habitat, was puzzling. This area was utilized by pronghorn, and mule deer may have prefered to avoid areas already being used by another ungulate with similar food habits. Since there was a large area of available summer habitat at the higher elevations compared to the limited lower elevation winter habitat, it is unlikely that lack of summer habitat or competition for forage in summer is a factor limiting deer populations on the Trickle Mountain study area.

4. Elk

Habitats used and preferred by elk were typical of habitats used by elk from other areas and consisted of areas with grasslands interspersed with heavier timber (Skovlin 1982).

The elk appeared to avoid the main Highway 114, which runs along the southern edge of the study area. However, the study area has numerous secondary dirt roads and jeep trails. There was no obvious avoidance of these roads.

D. Summary and Conclusions

Observations of animals from the ground and from aircraft were used to delineate boundaries of seasonal ranges for each of the 4 wild ungulates on the Trickle Mountain study area. Due to the diversity and interspersion of habitat types, correlations of such observations with habitat features and/or vegetation types and with weather conditions was impractical. Seasonal ranges used by each ungulate species and the use of particular habitats types within such ranges generally conformed to reported habitat preferences of the species in other areas. Seasonal ranges as mapped from direct observation were the most practical measures for incorporating ungulate distributions into a forage allocation model.

V. DIETARY OVERLAP AND POTENTIAL FOR COMPETITION

A. Methods and Materials

The method for obtaining estimates of seasonal diets of 6 ungulate species on the study area is described in Section III.

Overlap of ungulate diets, both within and between seasons, was determined using Kulcyznski's index of similarity (Oosting 1956): Similarity Index = $[2w/\ \Sigma(a+b)]x100$, where w is the lesser percentage of a food item in the 2 diets and a+b is the sum of percentages of food items in the 2 diets. The index represents the percent of 2 diets that is shared between 2 herbivorous species.

B. Results

Dietary overlap within seasons among the 6 ungulate species ranges from 3% for horses and mule deer in summer 1978 to 76% for bighorn sheep and elk in spring 1978 (Table 15). Forage competition being mutual use of forages that are limiting to herbivores, it is useful to compare grazing-season diets of cattle to winter-spring diets of wild ungulates--assuming winter-spring forages limit the wild species. Comparison of grazing-season food habits of cattle with winter-spring food habits of wild ungulates shows a range from 13% for cattle and pronghorn to 61% for cattle and bighorn (Table 16).

C. Discussion

Within seasons, dietary overlap between ungulates tended to be highest in winter, particularly in the winter of 1978 which had les snow and greater forage avaivability than the winter of 1979. The lowest dietary overlap within seasons occurred between the ungulates that relied primarily upon grass (horses and, to a lesser degree, cattle) and those that relied primarily on browse (pronghorn antelope and, to a lesser extent, mule deer). Of the wild ungulates, bighorn sheep and elk consistently had the most similar diets, averaging over 45% during all seasons.

The number of horses on the Trickle Mountain area is so low and their season of use and distribution so limited that competition with other ungulates is unlikely to be important except possibly for winterfat. The greatest potential for wildlife-livestock competition involves cattle and the most likely effect is from cattle grazing plants that are needed by wild ungulates during the critical winter/spring period. Overlap with cattle diets is greatest for elk and bighorn sheep and relatively low for pronghorn antelope and mule deer.

Table 15. Dietary overlap among ungulates on Trickle Mountain study area as measured by Kulcyznski's Index.

Season	Bighorn Sheep	Pronghorn Antelope	Mule Deer	Elk	Cattle	Horses
Winter 1978						
Bighorn Sheep	100	67	57	76		
Pronhgorn Antelope	67	100	51	59		
Mule Deer	57	51	100	62		
Elk	76	59	62	100		
Spring 1978						
Bighorn Sheep	100	46	56	64	53	34
Pronghorn Antelope	46	100	58	33	16	8
Mule Deer	56	58	100	43	26	13
Elk	64	33	43	100	49	23
Cattle	53	16	26	49	100	46
Horses	34	8	13	23	46	100
Summer 1978						
Bighorn Sheep	100	42	20	45	54	38
Pronghorn Antelope	42	100	15	38	12	6
Mule Deer	20	15	100	14	7	3
Elk	45	38	14	100	44	21
Cattle	54	12	7	44	100	54
Horses	38	6	3	21	54	100
Fall 1978						
Bighorn Sheep	100	47	32	48	47	
Pronghorn Antelope	47	100	47	31	17	
Mule Deer	32	47	100	40	19	
Elk	48	31	40	100	36	
Cattle	47	17	19	36	100	
Year-Round 1978						
Bighorn Sheep	100	53	50	62	52	35
Pronghorn Antelope	53	100	51	42	16	6
Mule Deer	50	51	100	48	22	10
Elk	62	42	48	100	45	27
Cattle	52	16	22	45	100	49
Horses	35	6	10	27	49	100

Table 15. (Cont'd.)

Season	Bighorn Sheep	Pronghorn Antelope	Mule Deer	Elk	Cattle	Horses
Winter 1979						
Bighorn Sheep	100	28	39	55		
Pronghorn Antelope	28	100	34	17		
Mule Deer	39	34	100	37		
Elk	55	17	37	100		
Spring 1979						
Bighorn Sheep	100	31	35	55	65	45
Pronghorn Antelope	31	100	56	42	20	9
Mule Deer	35	56	100	50	18	8
Elk	55	42	50	100	49	28
Cattle	65	20	18	49	28	56
Horses	45	9	8	28	56	100

Table 16. Percent overlap between winter/spring diet of wild ungulates and grazing season (June-October) diet of cattle. Overlap is measured by Kulcyznski's Index of similarity.[1]

Cattle	Bighorn Sheep		Pronghorn Antelope		Mule Deer		Elk	
	1978	1979	1978	1979	1978	1979	1978	1979
1978	47	60	17	18	25	25	40	52
1979	38	61	13	16	22	20	35	45

[1] Compared to 1978, the winter of 1979 had more abundant and continuous snow on the ground, limiting forage availability, and the spring of 1979 had more precipitation, producing an abundance of forbs.

Estimates of dietary overlap in the absence of other data are quite limited for assessing forage competition. Colwell and Futuyma (1971) point out that "simply demonstrating an overlap in resource use by two species in nature can be evidence either for or against the existence of competition between them." High overlap in forage use in a noncompetitive situation could occur on a range with an abundance of forages preferred by both ungulates. Conversely, low overlap with severe competition could occur where one ungulate species was utilizing the preferred and limited forages on the range prior to the arrival of a second ungulate. This situation, sequential competition, could occur when cattle are occupying a range during summer that is used by wild ungulates in winter. If the cattle had removed the preferred, presumably highest quality, forages for the wild ungulates, overlap in food habits might be low while competition for forage could be extreme.

D. Summary and Conclusions

Dietary overlap was measured by applying Kulcyznski's index of similarity to food habits data reported in section III. Within seasons, dietary overlap among the 6 ungulates on the Trickle Mountain study area ranged from 3% for horse and mule deer in spring to 76% for bighorn sheep and elk in spring. In general, dietary overlap was highest in winter and lowest in summer. Within and among seasons, dietary overlap was lowest between the grass eaters (cattle and horses) and the browse eaters (pronghorn antelope and mule deer). Dietary overlap, by itself, is of limited value in assessing competition between ungulates. A realistic forage allocation system must incorporate data, not only on seasonal diets of herbivores, but also on seasonal distributions of animals and on distributions and qualities of forages, if the system is to assess mutual uses of limiting forage resources.

VI. GROSS FORAGE CARRYING CAPACITY

Carrying capacity has been defined as "the maximum stocking rate possible without inducing damage to vegetation or related resources" (Kothman 1974). Gross carrying capacity may be determined by using vegetation production data adjusted for either allowable use factors (AUF's) or proper use factors (PUF's). The resultant carrying capacity is expressed in terms of animal unit months (AUM's). An AUM is "the amount of forage required by an animal-unit for one month" (Kothman 1974). An animal unit is defined as "one mature (1000 lb) cow or the equivalent based upon average daily forage consumption of 26 lbs dry matter per day" (Kothman 1974).

A. Methods and Materials

Forage production for all BLM lands within the study area was determined during 1978 and 1979 using the BLM's Soil Vegetation Inventory Method (Baker 1981). This produced estimates of dry-weight forage production by allotment. For a gross determination of carrying capacity the total forage production was multiplied by an AUF of 40 percent and divided by 780 (lbs/AUM).

For a more refined analysis, proper use factors for each forage species were multiplied by the production of the species and the products were summed to provide an estimate of usable forage. This figure was then divided by 780 to provide an estimate of carrying capacity in AUM's.

B. Results

Gross carrying capacities calculated using AUF's, for 7 allotments ranged from 667 to 6,506 for a total of 20,068 AUM's (Table 17). Carrying capacities calculated using PUF's (Table 18) ranged from 235 to 2,635 for the 7 allotments, for a total of 8,081 AUM's (Table 17). Current licensed use by livestock is for 3,247 AUM's and there is an estimated 5,867 AUM's of wildlife use (Table 19).

C. Discussion

Gross carrying capacity as calculated by 2 methods here has some obvious deficiencies. However, it provides a rough estimate of carrying capacity and illustrates long-established methods for determining stocking rates. These estimates thus serve as a useful reference point for comparing carrying capacities predicted from the same data by more modern methods and more complex calculations.

Table 17. Forage production, carrying capacities calculated with the use of AUF's and PUF's, and licensed livestock use for BLM lands within the Trickle Mountain study area.

Allotment	Dry Weight Forage Production (1000 lbs)	Carrying Capacity (AUM's) Calculated through the use of AUF's[1,2]	Carrying Capacity (AUM's) Calculated through the use of PUF's[1,3]	Current Licensed Livestock Use (AUM's)[4]
Laughlin Gulch[5]	5,445	2,792	862	426
Poison Gulch[5]	12,687	6,506	2,635	875
Cross Creek	6,291	3,226	1,397	358
Trickle Mountain	9,595	4,920	2,121	1,005
Sheep Creek	1,301	667	398	225
Taylor Canyon	1,972	1,011	433	245
Robb Ranch	1,845	946	235	113
Total	39,036	20,068	8,081	3,247

[1] The AUF is 40% for all species.

[2] An AUM is considered here to be 780 pounds of forage.

[3] The PUF's were taken from tables developed for the Canon City District, BLM; the values for summer cattle grazing were used.

[4] From Allotment Management Plans, Alamosa Area Office, BLM.

[5] Only the portion of this allotment north of Highway 114 is considered.

Table 18. Forage production (FP) and usable forage production (UP) by major forage species and allotment, Trickle Mountain study area.[1,2]

FORAGE	PUF[3]	Laughlin Gulch		Poison Gulch		Cross Creek		Trickle Mountain		Sheep Creek		Taylor Creek		Robb Ranch	
		FP	UP	FP	UP	FP	UP	FP	UP	FP	UP	FP	UP	FP	UP
Grass and Grasslike Plants															
Arizona fescue (Festuca arizonica)	0.60	159	95	930	558	256	154	702	421	66	40	52	31	14	8
Blue grama (Bouteloua gracilis)	0.60	502	301	752	451	474	284	858	515	82	49	136	82	144	86
Bottlebrush squirreltail (Sitanion hystrix)	0.30	28	8	381	114	193	58	283	85	93	28	98	29	5	2
Muhly (Muhlenbergia sp.)	0.30	172	52	673	202	229	69	613	184	155	47	55	17	32	10
Prairie junegrass (Koleria cristata)	0.50	42	21	223	112	83	42	311	156	4	2	2	1	11	6
Sedge (Cyperaceae)	0.50	112	56	449	225	306	153	243	122	188	94	235	118	51	26
Wheatgrass (Agropyron spp.)	0.60	3	2	40	24	14	8	39	23	1	1	6	4	—	—
Other Grass	0.50	84	42	162	81	183	92	39	20	65	33	7	4	24	12
Forbs															
Goosefoot (Chenopodium sp.)	0.05	294	15	790	40	559	28	90	5	6	—	140	7	121	6
Hymenoxys (Hymenoxys sp.)	0.00	145	—	859	—	258	—	1,004	—	78	—	196	—	134	—
Lupine (Lupinus sp.)	0.20	69	14	561	112	478	96	6	1	28	6	—	—	32	6
Mustard Brassica sp.)	0.05	111	6	942	47	627	31	335	17	80	4	425	21	202	10
Other Forbs	0.00	453	—	936	—	541	—	940	—	128	—	287	—	85	—

																Total
Browse																
Cactus (Cactaceae)	0.00	2,441	—	1,780	—	408	—	391	—	—	—	7	—	824	—	
Rabbitbrush (*Chrysothamnus* spp.)	0.00	502	—	1,781	—	835	—	2,196	—	154	—	96	—	67	—	
Sagebrush (*Artemisia* spp.)	0.10	33	3	218	22	353	35	897	90	70	7	170	17	52	5	
Winterfat (Eurotia lanata)	0.40	129	52	49	20	65	26	19	8	—	—	18	7	7	3	
Yucca	0.10	59	6	472	47	142	14	82	8	—	—	—	—	26	3	
Other Browse	0.00	106	—	688	—	287	—	553	—	112	—	43	—	13	—	
Total Usable Forage			673		2,055		1,090		1,655		311		338		183	6,305
AUM's			862		2,635		1,397		2,121		398		433		235	8,081

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[1] FP = forage production as measured using Soil Vegetation Inventory Method (BLM 1978) expressed in 1,000 lbs.

[2] UP = usable forage production determined by multiplying forage production for a forage species by proper use factor (PUF) for that species; expressed in 1,000 lbs.

[3] PUF = proper use factor, defined here as "the percentage use that is made of a forage species under proper management"; values used were derived from tables for Canon City District, BLM.

1. Limitations of the AUF Approach

Use of AUF's has the obvious deficiency that such values have never been scientifically developed (Skiles et al. 1980a). The Society For Range Management defines allowable use a "the degree of use estimated to be proper until proper use is known" (Kothman 1974). Current use defines AUF in terms of a plant's physiological response to grazing: "the amount of above ground plant parts which can be grazed and still allow the plant to recover" (Skiles et al. 1980b). Since AUF values are not available for the Trickle Mountain area, a value of 40 percent was used for all plant species. The Society for Range

Table 19. Wildlife forage demand from BLM lands within Trickle Mountain allotment expressed as animal unit months (AUM's).

Species	Number of Animals	Months	Animal Months	AUM Equivalents[1,2]	AUM's
Bighorn sheep	150	9	1,350		959
	150	12	1,800		1,278
	300		3,150	0.71	2,237
				(0.11)[3]	(237)[3]
Pronghorn Antelope	150	12	1,800	0.15	270
Mule Deer	500	6	3,000	0.26	780
Elk	500	6	3,000	0.86	2,580
				(0.34)[4]	(1,020)[4]
Total					5,867
					(2,417)[5]

[1] Based upon an AUM of 780 lbs of forage.

[2] AUM equivalents are calculated using monthly forage intake rates of 8.3 kg/day (18.3 lb/day) for bighorn sheep, 1.8 kg/day (4.0 lb/day) for pronghorn antelope, 3.0 kg/day (6.7 lb/day) for mule deer, and 10.2 kg/day (22.4 lb/day) for elk.

[3] Alternative AUM equivalent and AUM's based upon an intake rate of 1.3 kg/day (2.9 lbs/day) of dry forage reported by Chapell and Hudson (1978).

[4] Alternative AUM and AUM's equivalent based upon an intake rate of 4.0 kg/day (8.8 lb/day) of dry forage as suggested by Eastman (1981).

[5] Calculated using alternative AUM figures for bighorn sheep and elk.

Management states with regard to allowable use that "thirty to fifty percent of the annual growth by weight is often used as a rule of thumb on ranges in good or excellent condition" (Kothman 1974). Use of one value for all forage species, however, implies that all species on the range will be grazed with equal intensity, i.e., that grazing animals are non-selective feeders. This is an unreasonable assumption.

2. Limitations of the PUF Approach

The concept of proper use allows for selective foraging by herbivores. The proper use factor is defined as "the percentage use that is made of a forage species under proper management" (Stoddart et al. 1975). The definition is somewhat circular. It implies that if some forage species are preferred, the less preferred species will have PUF's that are lower than the AUF values based upon physiological abilities of the species to withstand grazing. Thus PUF's take into account the forage selection patterns of ungulates grazing the range. They are therefore dependent upon the numbers and species of ungulates present and also on the plant species composition of the range as well as numerous other site-specific factors (Skiles et al. 1980b). However, PUF's have never been determined in a scientific manner (Skiles et al. 1980b). Therefore, the gross carrying capacity presented above, based on PUF's, should be used with caution.

For this analysis PUF's were derived from tables, developed by the Canon City District of the BLM. PUF values for summer cattle use were used since this is the species and season that accounts for most of the livestock grazing. Ideally, PUF's would be available for a range with similar plant species composition being grazed by all 6 Trickle Mountain ungulate species in approximately the same numbers. In spite of these limitations, the predicted carrying capacity (8,081 AUM's) is within 15% of the calculated actual use (9,114 AUM's) by both livestock (3,247 AUM's) and wildlife (5,867 AUM's).

3. Variation in AUM Equivalent Values

The above estimate for wildlife AUM's may be high because of the conversion factors (AUM equivalents) used. The conversion factors were developed using minimum forage intake rates specified in a BLM memorandum (U.S. Bureau of Land Management) by dividing those rates by the standard 780 lb/month AUM for a mature cow:

$$\frac{\text{wildlife species forage consumption for 1 month (lbs)}}{\text{cattle forage consumption for 1 month (780 lbs)}} = \text{AUM Equivalent for for wildlife species}$$

Forage intake rates for wildlife are of course dependent on several factors, including season (Moen 1980) and body weight (Skiles et al. 1980c). Nevertheless, the BLM values for elk and bighorn sheep appear to be too high. Eastman (1981) suggested an intake rate of 4.0 kg/day (8.8 lb/day) for Rocky Mountain elk, which converts to an AUM equivalent of 0.34 or less than half the BLM value. Similarly Chapell and Hudson (1978) determined an average intake rate of 1.3 kg/day (2.9 lb/day) for bighorn sheep which provides a calculated AUM equivalent value of 0.11, less than one-fifth the BLM value.

Use of these alternate equivalents provides a wildlife utilization of 2,417 AUM's and reduces the current total forage demand to 5,664 AUM's (Table 19), well below the carrying capacity of 8,081 estimated using proper use factors.

4. Factors not considered by the AUF or PUF Models

Given the limitations of the data and procedures, these carrying capacity values and associated forage demand values should not be taken to indicate by themselves that the range is over- or under-utilized. Even assuming that the cattle input data and forage intake rates are correct, a number of important biological factors are not considered. These include forage quality, population dynamics, foraging behavior and weather patterns. These factors are discussed in more detail in Section VII.

D. Summary and Conclusions

Gross carrying capacities for all BLM lands within the Trickle Mountain study area were calculated from data on forage production with the use of allowable use factors (AUF's) and proper use factors (PUF's). Estimates for carrying capacity of the Trickle Mountain study area based on these techniques were 20,068 and 8,081 AUM's respectively. This compares with current licensed livestock use of 3,247 AUM's. Current wildlife forage use was estimated at between 2,417 and 5,867 AUM's depending on the AUM equivalent figures used. These figures yield total forage demand, (from livestock and wildlife, of 5,664 and 9,114 AUM's respectively.

Limitations of the AUF and PUF methods are discussed. A number of important biological processes are not considered by either method; these include forage quality, population dynamics, foraging behavior and weather patterns.

VII. FORAGE ALLOCATION MODEL

A. Introduction

Simulation has been widely used in the last 15 years not only to increase our understanding of ecological systems (Paulik 1972), but also to assist decision makers in a wide variety of natural resource fields including forestry, wildlife management, fisheries, watershed management and many others (Watt 1966; Frankiel and Goodall 1978). As opposed to mathematical programming or other optimization approaches, simulation provides models with which to study the behavior of systems being managed under a wide range of conditions. As such, simulation will not produce directly an "optimum" solution to a problem such as forage allocation. However, it will allow a user to predict the consequences of various alternative allocation decisions. These alternatives and their predicted consequences can then be evaluated by managers and by the public.

B. Previous Studies

The model presented here is designed to simulate effects of forage removal by several species of wild and domestic ungulates on rangeland vegetation and also the consequent feedback effects upon the animals. It has been constructed by using ideas and concepts from a number of existing models and modeling approaches.

1. Animal Population Dynamics

Several models have been developed within the last 15 years to simulate year-to-year changes in densities of wild ungulate populations (Gross 1970; Walters and Gross 1972; Riffe 1970). These models utilize data on initial population density, sex and age structure, and age-specific birth and death rates, as well as imposed harvest rates in order to predict future population levels under given management strategies. Such models are now being used operationally by many western fish and wildlife agencies to assist wildlife managers in setting harvest quotas for elk, mule deer and pronghorn antelope (Pojar and Strickland 1979).

2. Plant Population Dynamics

Similar models have been developed for plant populations, particularly for forest lands. These models typically utilize birth and death rates (Leak 1970) although in other respects they may differ from animal population models. For example, because of the indeterminate growth rate of trees, many forest succession models utilize size classes rather than sex/age classes; the rates at which trees move from 1 size class to another are then governed by transition rates or probabilities (Waggoner and Stephens 1970). As with animal population dynamics models, these rates can be functions of population density or of external factors.

A major use of such models is in quantitatively predicting the pathways of succession (Shugart and West 1980), and predicting plant composition following perturbation due to factors such as fire (Catelino et al. 1979). The most common use of such models has been in the field of forestry where models are used to predict timber yields or regeneration of forest trees. However simulation models of plant populations have also been applied to such diverse problems as predicting deer browse production (Cooperrider and Behrend 1980a) and understanding factors regulating densities of weeds (Sagar and Mortimer 1975).

3. Animal Nutrition Models

Many workers in fields such as animal science, wildlife biology and animal physiology have developed models for predicting the efficiency of converting herbage to animal biomass as a function of herbage quality and animal characteristics. Recently years these models have been incorporated into more comprehensive models of animal production systems (Van Dyne et al. 1980).

Use of energetic measures of forage quality such as digestible energy or metabolizable energy to predict animal weight gain and/or survival has been a promising approach for both domestic livestock (Cook 1970) and wild ungulates (Cooperrider and Behrend 1980b). A particular advantage of such models is that measures of effective energy transfer from plants to animals allow development of models that can incorporate aspects of animal behavior such as the energetic cost of foraging and the energy cost of severe weather (Moen 1973). Such models can be quite useful in understanding adaptations of wild ungulates for efficient utilization of range resources on a year-round basis (Moen 1978).

4. Ecosystem Models

In recent years numerous holistic models have been developed to deal with the dynamics of plants and animals simultaneously. The most ambitious of these efforts have been the ecosystem models developed as part of the U.S. IBP Biome modeling programs reviewed by Watt (1975). These models typically incorporate abiotic features such as soil and water and are driven by weather variables, particularly rainfall and temperature. Generally they utilize a minimum of empirical data and utilize differential or difference equations to predict flows of energy or biomass from one state variable to another. However, matrix models of livestock grazing on rangelands that are based on empirical data have also been developed (Redetzke and Van Dyne 1980).

Although such ecosystem models have not been designed for analyzing forage allocation, many can and have been used to gain insight into alternative allocation strategies. Few if any simulation models have been developed for the explicit purpose of analyzing effects of alternative forage allocation strategies on vegetation and on 2 or more competing species of wild and domestic ungulates. Goodall (1967) described a model designed to simulate the effect of grazing by domestic sheep on range vegetation and the feedback effect on weight gain and mortality of sheep. However, to our knowledge this approach has not been expanded to include competing ungulates or other wild herbivores.

C. Criteria for a Forage Allocation Simulation Model

Our research has been directed toward producing a model that can be used by BLM field personnel in the preparation of Grazing Environmental Impact Statements (EIS's), allotment management plans (AMP's), habitat management plans (HMP's), and other documents which incorporate forage allocation decisions. Thus, selection of methodologies has been governed by the potential uses for which the model was designed. At the onset of the project, several criteria were developed for a forage allocation simulation model to be used by the BLM or similar agencies. These criteria have guided our efforts in model development and may aid in understanding why certain approaches or modeling techniques were chosen.

1. Realistic

Carpenter (1980) noted that traditional approaches to forage allocation have been designed for allocating forage to 1 or more species of livestock and do not realistically represent the complex behavior and nutritional and habitat requirements of wild ungulates. Thus a simulation model should realistically model certain aspects of animal ecology. Some of these aspects are listed here.

a. Forage Quality

Many allocation systems consider forage quantitatively but do not consider forage quality. Some early workers considered forage quality to be even more important than quantity in determining carrying capacity for both livestock (Cook and Harris 1950) and wild ungulates (Leopold 1950). This association is not universally accepted and some feel that due to the adaptability of large ruminants, forage quantity is more important than forage quality to these animals (Holechek 1980).

However, a great deal of research and management on wild ungulates has demonstrated the importance of forage quality and much effort is being expended to develop carrying capacity models based on nutritional requirements (Moen 1973; Mautz 1979; Wallmo et al. 1977).

b. Population Dynamics

Many forage allocation systems treat animal populations as if all animals were equal with regard to forage intake rates, nutrient requirements, etc. Adult wild ungulates require sufficient forage to maintain themselves above a starvation level; however, such a maintenance level for individuals will not ensure maintenance of the population. Available forage must be of sufficient quantity and quality to provide for the requirements of pregnant and lactating females and for growing young animals. Thus, population dynamics of wild ungulates are an important consideration. Fluctuations in ungulate populations are largely a function of the number of adult females that have adequate forage to produce viable offspring and the number of such young that can survive to breeding age. Both reproduction and survival of young are affected by nutritional plane of the animals. Furthermore, the nutritional requirements of these animals are substantially higher than for other sex and age classes.

c. Foraging Behavior

Foraging is an extremely complicated behavior. Species of wild ungulates have definite preferences for habitat types as well as for plant species and for plant parts that they eat. Realistic models of foraging must incorporate these considerations. In addition, temporal patterns are important. A large body of theory has been developed to account for foraging behavior of animals (Schoener 1971; Pyke et al. 1977). Yet we are unable to predict with much precision how and where an animal will forage at a given time. Most food habits data suggest that ungulates, by eating the best or most preferred plant species are continuously "high-grading" the forage supply. As a result, timing of when an animal utilizes a range is an important determinant of the quality of forage that will be available to it and thus determines its food habits and nutritional intake.

d. Weather Patterns

Weather patterns have a strong influence not only on forage production but also on forage availability. In particular, deep snows can make forage seasonally unavailable to ungulates. Furthermore, weather patterns on arid western rangelands of the United States can be quite variable.

The above concepts indicate a few factors which have been shown by numerous studies to be important determinants of carrying capacity for wild ungulates. These factors should be incorporated into allocation models whenever adequate data and/or predictive algorithms are available.

2. Quantitative

While models need be realistic, they should also be quantative. Models should be based on measurable factors in the environment and should provide quantitative predictions. Many factors that we know or suspect influence a multi-species grazing system cannot be quantified. For example, numerous studies have demonstrated or suggested that elk will avoid foraging in areas where cattle are present, thus making forage unavailable to elk (Sauer 1980; Mackie 1978; Knowles 1975). However, we do not know enough about this phenomenon to quantify it; therefore it must be left out of current allocation models.

3. Data Based

A model for the BLM must be designed to utilize data that are available and/or which the BLM is committed to collect. The BLM has been directed by Congress to maintain a current inventory of resources on the public lands (Federal Land Policy and Management Act of 1976). Vegetation provides many commodity and amenity values such as scenic value, watershed protection and wildlife cover in addition to forage for animals. Current BLM vegetation surveys are designed to provide data for analyzing these values while also predicting forage production. To implement cost efficient inventory and planning procedures, those concerned with particular problems such as forage allocation should use these common data bases rather than propose new procedures for single purpose inventories.

In addition, forage allocation models should be based as much as possible on empirical data. Our limited understanding of grazing ecosystems and the controversial nature of allocation decisions provide good justification for utilizing empirical measurements rather than theory whenever possible.

4. Usable

An allocation model for the BLM should be designed for use by field offices in terms of utilizing their available computer facilities and in addressing their specific problems. Within the last 2 years remote computer terminals have been installed in most field offices, therefore hardware is not a limiting factor. However many BLM areas have specific ecological situations that warrant unique local consideration. A simulation model should be of modular design so that it can easily be adapted to a specific situation, and so that field personnel can specify their own parameters or design new algorithms where appropriate.

5. Unbiased

There are a diversity of possible management objectives for rangelands. These objectives can be influenced by forage allocation decisions. The BLM is required by law (National Environmental Policy Act of 1973, PL 91-190; Federal Land Policy and Management Act of 1976, PL 94-579) to both consider alternatives in land management decisions and present such alternatives for review. The BLM's planning procedures are designed to ensure consideration of management alternatives. Since forage allocation is an important and often controversial component of land management plans, a model should provide objective, unbiased predictions related to a variety of alternative objectives and their associated impacts.

6. Legally Defensible

Any model used by the BLM for forage allocation map eventually be tested in the legal system through the appeals procedure. Modeling procedures should be legally defensible as well as biologically sound. Many environmental laws of the last 2 decades such as the Clean Air Act of 1970 and the Clean Water Restoration Act of 1966 require development of complex systems models for evaluating impacts of a given project on air or water quality, and these models have been tested in court. For example, in court cases involving air quality, results from 1 model are often used to appeal a decision based on another model (Loucks 1972). Certain types of models are easier to defend in court. Models that are based as much as possible on empirical data have been most easily defended.

D. Data Bases

The simulation model presented here is a data based, difference equation model utilizing site-specific data on habitat, ungulate populations and weather. It is designed to utilize data that are being collected by the BLM or which are available to BLM biologists from other sources.

The model predicts forage removal from a set of habitat types as a function of the standing crops of forage, densities of big game and livestock, seasonal trends in animal distribution and forage preferences, weather patterns and previous forage removal. Predicted forage removal by ungulates is used to estimate trends in qualities of diets. Impacts upon animal weight changes, reproduction and mortality are predicted from diet qualities and nutritional requirements of animal species. In this subsection, the data bases utilized by the model are described. In the following subsection the mechanics of the model are documented.

Data bases utilized in our model are of 4 types: habitat data, population data, weather data, and basic biological data. The first 3, represented by boxes and ovals in Figure 16, are site-specific data that must be collected from a particular area being modeled and represent the initial values of state variables in the model. Basic biological data, on the other hand, are more universal relationships used to define parameters which govern flows among state variables. For our allocation model these latter data have been gathered from the scientific literature.

1. Habitat Data

Three types of "habitat" data need be collected for use in the model: forage production, habitat use, and food habits.

a. Forage Production

Data on the number of plants per acre and the average weight per plant at each phenological stage are collected for each major plant species within each stratum or habitat type on each allotment. These data can be gathered according to the BLM's Soil Vegetation Inventory Method (SVIM). The standard SVIM procedure involves a 1-time measurement of standing crop of vegetation. Species adjustment factors based on percentage of maximum production at each phenological stage are used to calculate total production by species. These adjustment factors are derived by clipping and weighing plants at each phenological stage.

b. Habitat Use

The habitat sites used by each ungulate species and season are determined. Again, this is data to be gathered by BLM biologists for a particular area. The data may involve either a determination of "use" or "no-use" or a relative preference for each type. In the simplified case, areas that are unused during a given season would be assigned a 0 and those that are used would be assigned a 1. If, however, data are available on degree of utilization or preference, then any values from 0 to 1 may be assigned depending on relative preferences for a habitat.

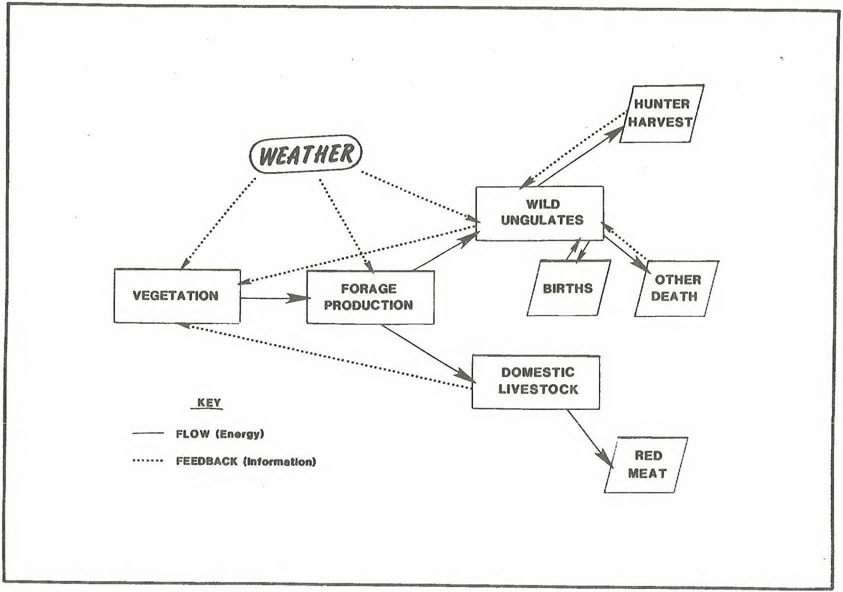

Figure 16. Major variables and flows in a grazing system with livestock and wildlife.

c. Food Habits

The percentage of each major plant species in the diet of each ungulate is determined by season. These data are gathered for the particular area being modeled through fecal analysis or other appropriate techniques. In a few cases, suitable data are available in the literature. The data are not used directly in the model but rather are used with the forage production data to determine a relative preference index for each plant species in each season (Krueger 1972). The forage preference index $FP_{i,j}$ may be calculated from data on available forage and on food habits as:

$$FP_{i,j} = \frac{\text{percent of plant species } j \text{ in diet of animal species } i}{\text{percent of total available forage composed of the plant species } j}$$

These preference indices can be calculated at several times of year corresponding to phenological stages of plants in order to determine preference indices that are specific for phenological stages.

2. Population Data

The numbers of ungulates in each sex and age class of each ungulate species are determined or estimated. Generally, the number and classes of livestock on each allotment are known. Data on wild ungulates on the other hand are generally obtained from state wildlife agencies or collected in co-operation with such agencies. For meaningful simulations, at least 6 sex-age classes are distinguished: young of the year, yearlings, and adults, for each sex.

3. Weather Data

Weather records may be used to increase realism of the model. For our test area we have used records of snow depths from a nearby base weather station and snow depth measurements on the range to develop predictive equations for determining average snow depth on each habitat site as a function of base station snow depth, and elevation and aspect at each site. This equation allows use of snow depth data from any of the past 25 years to simulate the distribution of snow on the range during severe, mild or average years. Snow depth data are used primarily to predict if forage is available to wild ungulates on each habitat site.

Weather records of temperature and precipitation may also be used to simulate the year-to-year variation in forage production as a function of effective precipitation; however, we have not developed this subprogram. The BLM is currently sponsoring research to quantify this relationship.

4. Basic Biological Data

Data in this category are used primarily to quantify the flows in Figure 16, as opposed to providing initial values for the state variables in boxes and ovals. Data include measurements of nutritional qualities of forages, nutritional requirements of ungulates, and population dynamics parameters of wild ungulates. These data tend to be less site-specific and we have taken values from the scientific literature. Model users would not normally have to determine or specify these on a site-specific basis, although they would have this option.

E. Description of the Model

1. Components

The major variables of the simulation model are of 4 types: driving variables, system variables, parameters, and independent variables (Table 20).

a. Driving Variables

The only driving variable of the model is weather, which currently is limited to snow depth. The system may be considered to be driven by forage production in that forage is the source of all energy flows (Fig. 16). However, it is traditional to define driving variables a those which are dependent only on time and therefore are exogenous to the system (Bledsoe et al. 1971). In this sense forage production is not a driving variable since it is affected by the system (Fig. 16).

b. System Variables

The principal system variables consist of the numbers and weights of wild ungulates, livestock, and plants. The wild ungulates are divided into sex and age classes, whereas livestock are separated by class only (e.g. cow, calf, steer, etc.) since their population dynamics are not of concern. Plant variables consist of the number of plants or stems in each habitat type or stratum of each allotment, and the weight of forage produced per plant per phenological stage. Numerous intermediate system variables are calculated from the principal system variables. The major ones are listed in Table 20.

Table 20. Variables of simulation model

Type	Symbol$_{a,b}$	Definition	Units	Nominal Value or Range
Driving Variables				
Snow Depth	S_t	Base station snow depth at time t.	cm	
Principal System Variables c/				
Wild Ungulate Numbers	$U_{i,m,n}$	The number of animals of species i in sex class m and age class n.		
Wild Ungulate Weights	$UW_{i,m,o}$	The weight of an individual animal of species i in sex class m and age class o.	kg	
Livestock Numbers	$L_{i,c}$	The number of animals of livestock species i in class c.		
Livestock Weights	$LW_{i,c}$	The weight of an individual animal of livestock species i in class c.	kg	
Number of Plants	$P_{j,k,l}$	The number of plants of plant species j in habitat type k of allotment l.		
Weight per Plant	$W_{j,p}$	The weight of a plant of plant species j in phenological stage p.	kg	
Parameters				
Phenological Stage	$PH_{j,t}$	The phenological stage of plant species j at time of year t. This is also indicated by subscript p.		$1 \leq PH_{j,t} \leq 8$
Caloric Density	$CAL_{j,p}$	The digestible energy (DE) density of plant species j in phenological stage p).	kcal DE/kg	$1.0 \leq CAL \leq 3.8$

Table 20. (continued)

Type	Symbol[a,b]	Definition	Units	Nominal Value or Range
Parameters (continued)				
Habitat Preference	$HP_{i,k,l,t}$	The relative preference of animal species i for habitat type k of allotment l at time period t.		$0.0 \le HP \le 1.0$
Forage Preference	$FP_{i,j,p}$	The relative preference of animal species i for plant species j in phenological stage p.		$0.01 \le FP \le 20.0$
Birth Rates	$B_{i,n}$	The average number of young produced annually by females of animal species i of age class n.		$0.0 \le B \le 2$
Death Rates	$D_{i,m,n}$	The average percentage of animals of species i of sex class m and age class n that die annually from disease, predation and accidents.		$0.0 \le D \le 1.00$
Independent Variables				
Time	t	Time of year measured in 2-week increments.		
Intermediate System Variables [c]				
Weight of Forage	$F_{j,k,l,t}$	Weight of forage for each plant species j within habitat type k on allotment l at time t.	kg	
Available Forage	$AF_{i,j,t}$	The weight of forage of plant species j available to animal species i at time t.		
Dietary Composition	$DT_{i,j,t}$	The percentage of plant species j in the diet of animal species i at time t.		$0.0 \le DT \le 1.0$

Table 20. (continued)

Type	Symbol$_{a,b}$	Definition	Units	Nominal Value or Range
Intermediate System Variable (continued) c/				
Weight in Diet	$WD_{i,j,t}$	Weight of each plant species j in the diet of animal species i during time t.	kg	
Forage Intake	$FI_{i,t}$	Total forage intake of animal species i during period t.	kg	
Weight Change	$WG_{i,n,m,t}$	Change in weight of individuial of age class n, and sex class m of animal species i at time t.	kg	

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[a] Key to subscripts:

i = ungulate species
j = plant species
k = habitat type
l = allotment
m = sex class of ungulates
n = age class of ungulates
p = phenological stage
c = class of livestock
s = season

[b] Subscripts preceded by n indicate the number in that class; e.g., n_i indicates the number of ungulate species.

[c] Principal system variables are the major variables of concern and must be specified at the initiation of a simulation;

[d] Intermediate system variables are calculated from principal system variables.

c. Parameters

Major parameters of the model (Table 20) are the phenological stages of plant species as a function of time of year, the nutritional values of major forage species, the relative preferences of animals for forage species and for habitat types, and the birth and death rates of wild ungulates. In addition, parameters for equations such as those predicting intake rates and growth rates must be specified. The latter parameters and associated functions will be discussed under "Dynamics".

The phenological stages of plants are a function of time of year. Eight phenological stages are distinguished: beginning growth, vegetative stage, boot stage, peak of flowering, seed ripe, mature, dormant, and regrowth. These are stages recognized and utilized in SVIM inventories. For each 2-week period in the year a phenological stage is designated for each plant species. Thus there is a fixed cycle of phenology that is driven by the matrix $PH_{j,t}$.

Nutritional values of forages are expressed as densities of digestible energy (Kcal DE/g forage).

Preferences for forage species (FP) and for habitat types (HP) are expressed as positive numbers, with FP = 0 indicating a plant species not eaten, FP=1 indicating a plant species neither avoided nor preferred and FP>1 indicating a preferred plant species. In practice values of FP are restricted to the range $0.01 \leq FP \leq 20$. Habitat preferences range from 0 to 1 with HP=1 indicating habitat type that is preferred by an ungulate species. In the case where only "use" or "no-use" of a habitat type is known, these categories may be expressed as HP=1 and HP=0.

Birth parameters are the age-specific birth rates of each wild ungulate species. Death parameters are the sex and age specific "background" death rates. Background death rates are considered death due to predation, diseases and accidents since starvation death and hunter kill are modeled independently.

d. Independent Variables

The only independent variable is time, t. The model uses a year divided into 26 2-week periods.

2. Dynamics

Dynamics are expressed as a series of difference or recurrence equations coded in FORTRAN IV. The time interval for calculations is 2 weeks except for such events as birth that occur less frequently. The dynamics of the model can be divided into 3 categories: plant dynamics, animal dynamics, and the link between these 2, forage removal.

a. Plant Dynamics

The weight of forage ($F_{j,k,l,t}$) for each plant species j, within a given habitat type k, on each allotment l, is calculated from the weight per plant $W_{j,p}$ for the appropriate phenological state p, and the number of plants $P_{j,k,l,t}$ as follows:

$$F_{j,k,l,t} = W_{j,p} \cdot P_{j,k,l,t}$$

Because weight per plant ($W_{j,p}$) is a function of phenology, during the growing season, when phenological stages are changing, the available forage must be recalculated at each interval t.

b. Forage Removal

Foraging is simulated for each class of animal at 2-week intervals. Several processes are simulated to mimic animal foraging: choice of habitat, choice of forage, feedback on plant species, and feedback on animals (growth).

(1) Forage Available

Habitat types available for foraging are determined as a function of snow depth and seasonal habitat preferences. First, habitat types unavailable due to deep snow are elminated. Then the forage within each type with a preference index greater than 0 is summed by weighting the available forage by the habitat preference index (HPI). Thus, if an area has a HPI of 0.6 the contribution of that type toward total available forage is 60% of the forage present. The total forage available is then determined by summing by species or forage class all the forage available within all available habitat types. Thus:

$$AF_{i,j,t} = \sum_{p=1}^{nl} \sum_{k=1}^{nk} SF_{i,k,l,t} \cdot HP_{i,k,l,s} \cdot F_{j,k,l,t}$$

where:

$AF_{i,j,t}$ = the weight of forage of plant species j available to animal species i at time t

and

$SF_{i,k,l,t}$ = the degree to which snow depth prevents use of habitat type k of allotment l by ungulate species i at time t.

$HP_{i,k,l,s}$ = the relative preference for (use of) habitat type k of allotment l by species i during season s

and

$F_{j,k,l,t}$ is weight of forage as described above.

(2) Choice of Forage

Once the total available forage is determined, forage is chosen as a function of the amount of available forage of each species present ($AF_{i,j,t}$) and the relative preference ($FP_{i,j,p}$) for that species at its phenological stage. The percentage of each plant species j in the diet of animal species i ($DT_{i,j,t}$) will thus be:

$$DT_{i,j,t} = (AF_{j,t} \cdot FP_{i,j,p}) / \sum_{j=1}^{nj} (AF_{i,j,t} \cdot FP_{i,j,p})$$

The weight of each plant species in the diet of animal species i is a function of total forage intake for the period and the percentage ($DT_{i,j,t}$). Thus:

$$WD_{i,j,t} = DT_{i,j,t} \cdot FI_{i,t}$$

where

$FI_{i,t}$ = total forage intake of animal species i during period t.

Forage intake can be made a function of body weight (UW, LW) or metabolic body weight ($UW^{0.75}$, $LW^{0.75}$) where appropriate.

(3) Plant Feedback

The immediate short term feedback is that as forage is removed and fewer plants remain to produce forage.
Thus:

$$P_{j,k,l,t+1} = P_{j,k,l,t} - (WD_{i,j,t}/W_{j,p}) \cdot P_{j,k,l} \sum_{k=1}^{nk} \sum_{l=1}^{nl} P_{j,k,l}$$

These plants are not available to produce forage in the same growing season, however, they are available in future years or growing seasons. Long term feedback can also be modeled in which the number of plants available in future years declines as a function of the degree to which the allowable use factor (AUF) for each species is exceeded. Data available for modeling such overgrazing is quite limited, and the principal value of multi-year simulations of range deterioration is to demonstrate trends in plant and animal numbers rather than to quantify the rate of decline of density of plant species.

(4) Animal Feedback

The major feedback effect on animals is a weight loss or gain (WG) as a function of digestible energy (DE) intake and metabolic body weight as follows:

$$UW_{t+1} = UW_t + WG$$

where:

$$\begin{aligned} WG &= \text{weight change (kg)}, \\ &= a+b(DE/UW_t^{0.75}), \end{aligned}$$

and

$$DE = (WD_{i,j,t} \cdot CAL_{j,p}),$$

a,b are fitting parameters

Weight changes associated with starvation, birth and lactation are described under animal dynamics.

c. Animal Dynamics

Two principal types of animal dynamics are simulated, birth and associated processes, and death.

(1) Birth

Birth of wild ungulates is modeled as a discrete event occurring on June 1. At this time new animals are added to the first age class as a function of the number of reproductive females ($U_{i,m=2}$) and the age specific birth rates ($B_{1,n}$) as follows:

$$U_{i,n=1} = \quad (U_{i,m=2} \cdot B_{i,n})$$

where

$$m=2$$

The sex ratio at birth is assumed to be 50:50 unless otherwise specified. At the same time the entire remaining population is moved to new age classes such that:

$$U_{i,n,m,t+1} = U_{i,n-1,m,t}$$

At this time the weight of females is adjusted to account for birth. Similarly, the energy intake and loss of lactating females and nursing young are adjusted to account for lactation. Both adjustments are made following procedures described by Cooperrider and Behrend (1980b).

(2) Death

Three types of death for wild ungulates are simulated: background mortality (predation, disease, accidents), starvation, and hunter kill. The latter will be discussed under management.

Background mortality is considered to be the level of mortality that would occur in the absence of hunting and in the absence of any forage limitation on the herd. It is modeled as a function of the number of animals ($U_{i,m,n}$) and the age- and sex-specific death rate ($D_{i,m,n}$). Thus for a given sex and age class:

$$U_{i,m,n,t+1} = U_{i,m,n,t} - (D_{i,m,n} \cdot U_{i,m,n,t})$$

Starvation death is a function of the weight of the animal and can occur at any time of year. When animals of a given sex and age class lose more than a critical percentage of their normal weight, they are considered to have starved and are removed from the population.

3. Management

Of the flows shown in Figure 16, few are subject to control by man. In practice the number, classes and seasons of grazing of livestock can be closely managed. Similarly, the number of wild ungulates in each species can be influenced through hunter harvest. Any combination of numbers and classes of livestock, and seasons of use can be simulated by the model. Hunting harvest can be simulated using harvest rates similar to the mortality rates described under death. Hunter harvest is normally simulated as if it all occurs at one point in time, November 30.

F. Examples

Examples are presented here to illustrate the types of "what if" questions that can be addressed by simulation and to demonstrate the insight into system dynamics that can be provided by such a model.

A simulation analysis with real data has been made on each allotment on Trickle Mountain as well as for the entire area. These are primarily of interest to those dierectly concerned with managing of the area and require voluminous documentation of input and output. Therefore they are being prepared separately from this report.

Examples presented here are intended to illustrate the capability of the model rather than to represent our best or final predictions about the system. For this reason, initial inputs and parameters are described briefly without complete documentation.

1. Input Data - Plants

Total forage production (F) used for all simulations described here is based upon data on number of plants per ha (P) and weight per plant (W) obtained from the largest allotment within the test area. Phenologies of the plants (PH) were estimated from BLM records for the area, and caloric densities of forage species (CAL) were obtained from sources in the literature, particularly Cook et al. (1977). Caloric densities ranged from 3.72 kcal DE/g for highly palatable grass species such as gramagrass during early growth to an arbitrary 1.0 kcal DE/g for unpalatable forbs that are not eaten at all.

2. Simulation of Plant Dynamics

The above data can be used to simulate the standing crop of forage over time in the absence of any animal foraging and thus to illustrate some important temporal properties of the plant system. In the absence of foraging ungulates, roughly 30% of the total annual forage production is not present for half the year (Fig. 17). Thus standing crop, rather than production, is a better measure of what is seasonably available to ungulates. The annual cycle of energy production expressed as kilocalories of digestible energy per hectare follows the same basic pattern (Fig. 18) with over a third of the total energy being unavailable for half the year.

Combining information from the 2 graphs indicates that for over 7 months of the year average caloric density is below 2.2 kcal DE/g (Fig. 19). This caloric density is a calculated maintenance level for an ungulate such as a deer, using empirically derived equations for forage intake and growth (Appendix B). Thus an animal such as a deer would be in a negative energy balance for over half the year if it foraged on the "average" diet available.

3. Input Data - Animals

For initial simulations with ungulate populations we used an area of 40,000 ha (100,000 acres) which is approximately the size of the BLM lands on the Trickle Mountain study area. The simulated wild ungulate populations consisted of 300 bighorn sheep, 150 pronghorn antelope, 500 mule deer, and 500 elk. These are approximate numbers of animals present on the range. Sex and age structures were derived from Colorado Division of Wildlife estimates and body weights were obtained from the literature. Birth rates were based on the assumption that all female bighorn sheep age 3 and over produce 1 lamb per year, pronghorn age 2 years and over produce 2 kids per year, mule deer age 2 and over produce an average of 1.5 fawns per year, and elk age 2 and over produce 1 calf per year. Background death rates for animals under 1 year of age were 50% for bighorn sheep and pronghorn antelope, 40% for mule deer, and 30% for elk. A 10% annual death rate was used for all adult animals of all species, sexes and adult age classes. Harvest rates were derived from Colorado Division of Wildlife data and were 33% for adult male bighorn sheep over 2 years of age, 55% for adult male pronghorn antelope, 67% for adult male mule deer, 80% for adult male elk, and 10% for all other elk.

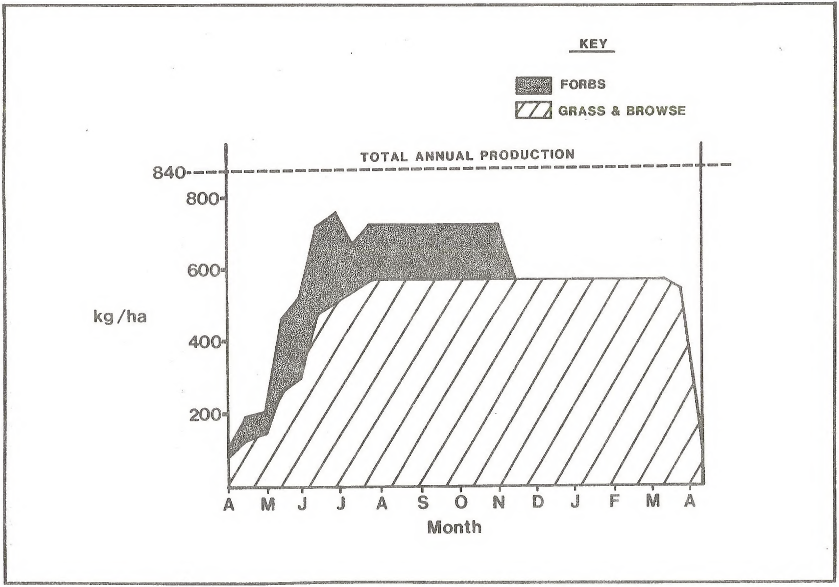

Figure 17. Simulated annual cycle of standing crop forage, Trickle Mountain, Colorado.

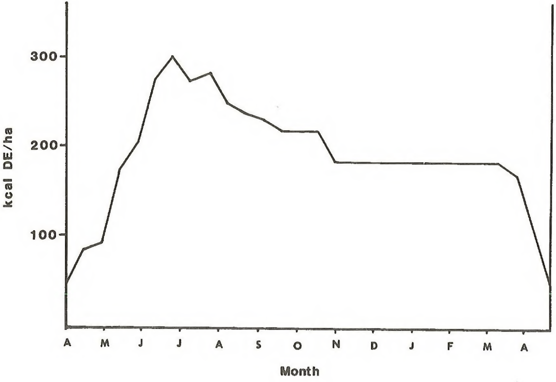

Figure 18. Simulated annual cycle of forage availability, expressed as kilocalories of digestible energy per hectare, Trickle Mountain, Colorado.

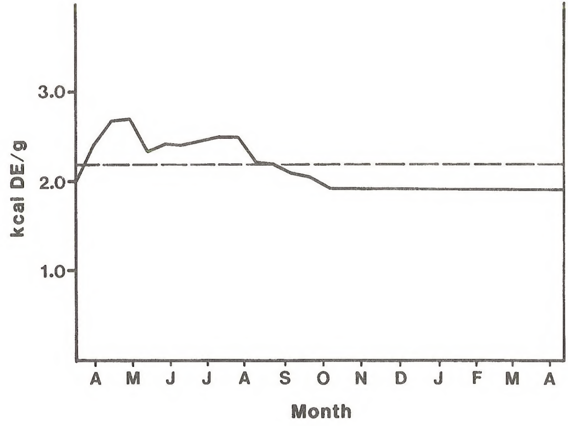

Figure 19. Simulated annual cycle of nutritional value of forage, Trickle Mountain, Colorado.

Forage preference values were derived from data on forage production and on food habits collected on Trickle Mountain as described earlier in this paper and ranged from 0.01 for unpalatable forbs such as hymenoxys to 20 for a highly palatable species such as mountainmahogany.

Forage production was assumed to be constant among years unless total use on a plant species exceeded an allowable use factor of 50%. When this allowable use was exceeded the forage production of that species was reduced in direct proportion to the degree of use beyond 50%, with a maximum reduction of 20% per year when utilization was 100%.

4. Simulation of Forage Allocation Alternatives

An initial simulation with 4 wild ungulates on 40,000 ha indicated that total forage production was not limiting any ungulate species and that allowable use was not exceeded on any plant species. With moderate summer-fall cattle grazing (up to 3000 AUMs), wildlife populations were unaffected, however, some highly palatable plant species such as mountain-mahogany were overutilized.

A more realistic situation was simulated by restricting wildlife populations to 2000 hectares (5000 acres) for 3 months of the year (January-March), the typical winter concentration pattern. Without livestock grazing on this winter range, the simulated wildlife population remained relatively stable or increased slightly. With livestock grazing on the winter range, however, the wildlife populations decreased. For example, with cattle grazing from July to December on the big game winter range, the bighorn sheep population is seen to decrease markedly when the number of cattle is increased from 100 to 300 (Fig. 20).

5. Sensitivity Analyses - Forage Quality

In sensitivity analyses 1 variable is systematically altered while other parameters are held constant. In a sensitivity analysis, using the above parameters and initial populations on a 40,000 ha area with a 2,000 ha winter range, the caloric density of forage was systematically changed. In successive simulations, the caloric densities were altered in increments of 0.1 kcal DE/g, going from -0.2 to +0.2 of the norm for all species at all phenological states. Changes in simulated population levels of mule deer and pronghorn antelope after 4 years were substantial with both increased and decreased caloric densities (Table 21). For example, the pronghorn antelope increased with higher caloric densities from 150 to 284 animals at the highest level but declined to 43 animals at the lowest value (Fig. 21). On the other hand, bighorn sheep and elk responded negatively to the lower caloric

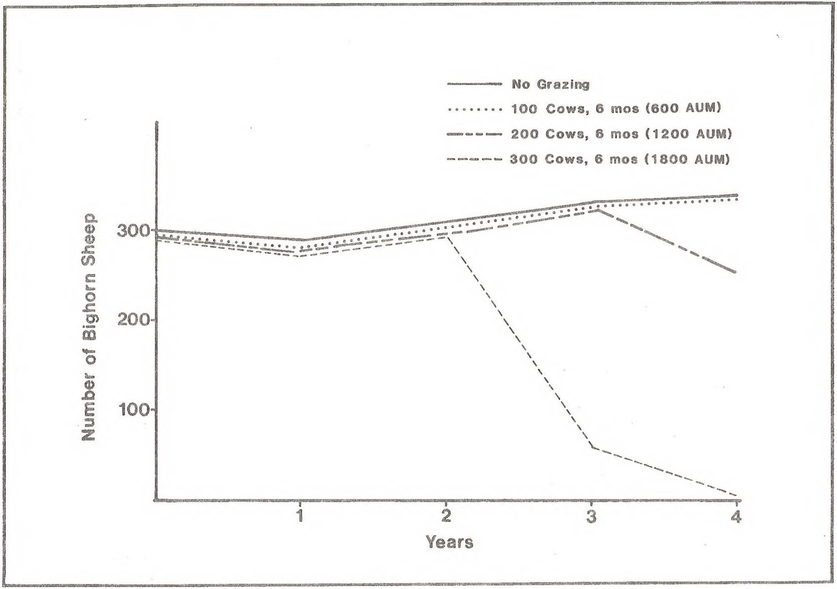

Figure 20. Simulated bighorn sheep populations with alternative livestock stocking rates.

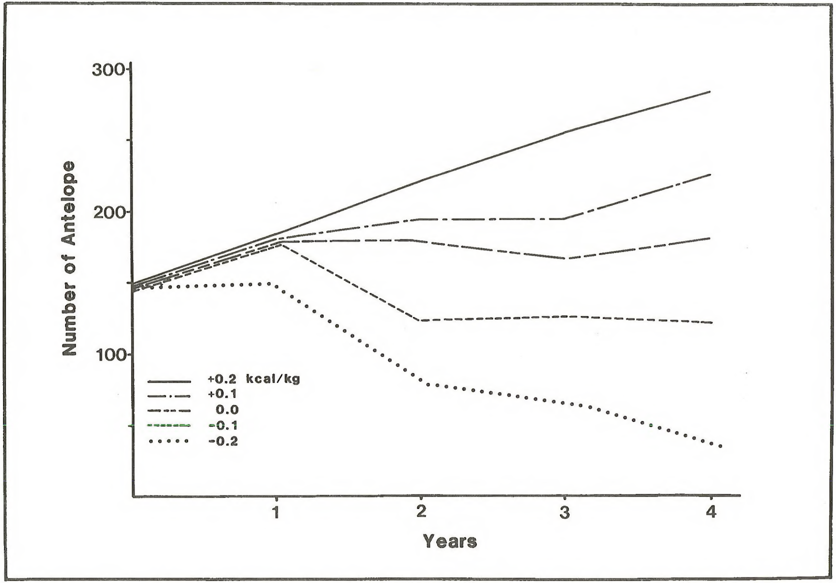

Figure 21. Simulated pronghorn antelope populations at varying caloric densities of available forage.

density values but did not increase in numbers with higher caloric densities. This suggests that forage quantity and quality are not limiting sheep and elk populations under these simulated conditions and raises the question of what is limiting their populations.

Table 21. Simulated total population sizes after four years with changes in average caloric density of forage.

Species	Initial Population Size	Change in Average Caloric Density				
		-0.2	-0.1	0.0	+0.1	+0.2
Bighorn Sheep	300	325	357	357	357	357
Pronghorn Antelope	150	43	121	181	226	284
Mule Deer	500	193	462	629	802	872
Elk	500	186	186	566	566	566

6. Simulation of Ungulate Population Dynamics

The model simulates harvest rates, birth rates and mortality rates in addition to mortality from starvation. If available forage is not a limiting factor, then management practices such as hunter harvest could be limiting population size. Using the above initial values and parameters (i.e. 4 species of wild ungulates on 40,000 ha year-round but restricted to 2000 ha for 3 months) we simulated the elk population with and without the normal 10% harvest of antlerless animals. Simulated elk population levels after 4 years were about 30% higher without the antlerless harvest (Fig. 22).

G. Discussion

The model described here does not contain any new modeling approaches but rather has been designed and constructed utilizing concepts and ideas from previous efforts to model forage allocation alternatives. The model allows incorporation of a large body of scientific information, particularly on animal nutrition and on ungulate population dynamics. In addition, it is tailored to utilize site-specific data on forage production and animal

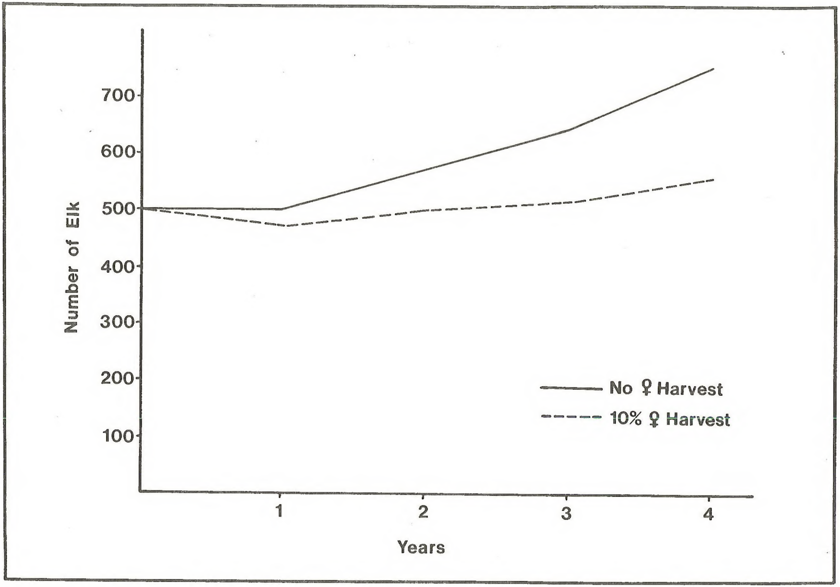

Figure 22. Simulated elk numbers with and without anterless harvest.

population densities and structures. As such it can incorporate a great deal of realism and is adaptable so that new knowledge or relationships can be added in the future. Because the model is not an optimization model, it is not limited to analyzing any one allocation objective, but can be used to gain insight and make quantitative predictions about a wide variety of situations and management options.

The above examples illustrate some of these properties. Simulation of plant dynamics illustrates the importance of recognizing the temporal pattern of forage production and deterioration. Total forage production is an abstraction and is never present on the ground at any 1 time. This has important consequences for forage allocation. For example, allocating forbs to an animal species such as mule deer that is present primarily during winter is not going to result in any additional available forage for these animals during this critical period.

The annual cycle of caloric densities shows the critical nature of the balance between forage supplies and forage requirements with which wild ungulates must cope. Winter weight loss is of course a normal phenomenon for a species like mule deer (Mautz 1978). However, weight must be gained at other times of year and this is especially critical for young animals and pregnant and lactating females. A primary value of the model described here is that it integrates the impact of forage quality and quantity on weight gains during other seasons with the impacts of winter weight loss in order to predict population effects.

Simulation of all Trickle Mountain ungulates at approximately normal levels indicates that total forage production is not limiting any wild ungulate population but that forage production in key areas such as winter ranges is a more likely limiting factor. The situations described here were simulated without utilizing some of the model capabilities such as submodels describing differential habitat utilization, and the effects of weather. Implementation of these capabilities may provide more insight into the complex nature of how forage can or does limit coexisting ungulate populations.

A consistent pattern that was noted in these preliminary simulations was that certain plant species such as mountainmahogany that have high preference values but are present in relatively low abundance are consistently overutilized even with low densities of ungulates on the range. This situation has been observed in the field on Trickle Mountain. Attempting to adjust numbers of livestock and/or wildlife so that such species are not grazed in excess of an allowable use factor is likely to result in unreasonably low estimates of the number of wild or domestic ungulates that can be carried on the range. For this reason, some authors have recognized that these "sacrifice" plants should not be used as utilization indicators (Stoddart et al. 1975). Simulation can assist managers in determining which species might be categorized as "sacrifice" species and also which plant species can better be used as "indicator" species.

The sensitivity of some of the simulated ungulate populations to small changes in caloric densities of forage may be viewed as either an artifact of the model or as a representation of a real phenomenon. If the relationship is real, then it supports the contention of those who feel that forage quality is more important than forage quantity in determining carrying capacities for wild ungulates.

Many ungulate populations are, of course, limited by factors other than quality or quantity of forage. Simulations such as the example of elk with and without a 10% harvest of antlerless animals can assist biologists and managers in understanding what factors might be limiting a wild ungulate population.

H. Summary and Conclusions

Simulation has been used in a number of natural resources fields to assist decision makers in understanding the resources being managed. Forage allocation to 1 or more competing ungulate species is a complex biological problem. The simulation approach to forage allocation allows a great deal of realism to be incorporated into a model of the biological system. It will not, however, produce directly a "solution" or "optimal allocation" for an area. Solutions for forage allocation problems will always depend upon goals. The simulation approach can be used to determine if and how goals can be achieved.

A simulation model was developed for use by the U.S. Bureau of Land Management (BLM) in analyzing forage allocation strategies. An attempt was made to incorporate a high degree of realism into a quantitative model that would use site-specific field data on forage production and ungulate populations and that could eventually be used operationally in field offices. A particular advantage of this simulation approach is that it can develop predictions about a variety of forage allocation alternatives or objectives and the associated biological consequences.

The model was constructed by borrowing ideas and concepts from existing models. Thus it incorporates in 1 model considerations of food and habitat preferences, plant dynamics, animal nutrition and animal population dynamics. Examples presented illustrate how the model can examine each of these phenomena either separately or in combination, and provide insight into the plant-forage-animal system, and develop predictions about the effects of forage allocation alternatives.

VIII. RECOMMENDATIONS

A. Introduction

Recommendations are divided into four categories (management, monitoring and studies, research, and modeling) and are discussed in subsections E through H. These recommendations concern primarily the wild ungulates and their management since this was the original purpose of the study; recommendations for livestock management are being provided to the area office separately.

Management recommendations for the Trickle Mountain area are based upon data collected during the study, results of the modeling, and experience from other areas. Recommendations for monitoring and studies are also site specific. These recommendations will interest primarily those directly concerned with managing the area.

Research recommendations include research needs suggested by the project or identified during the study. These relate to more general problems of interest in many areas throughout the BLM. Finally, in the section on modeling we present recommendations for future development and use of the forage allocation model.

Because of the diverse nature of the project, we have included subsections to place recommendations in context. Some techniques used in this study and used in developing recommendations are new, particularly the use of a computer model. Therefore, we present in subsection B a brief description of our philosophy of wildlife management and describe how data from this study have been used to develop recommendations. In subsection C we consider existing and alternative wildlife management objectives for the area and methods for achieving them. Because we believe that habitat management should be based upon manipulation of limiting factors, we present an analysis of limiting factors for the Trickle Mountain ungulates in subsection D. Recommendations for monitoring, an integral part of management, are in subsection F.

B. Context

For perspective, we briefly present our philosophy of wildlife management and our perception of the use of models in management. A more detailed presentation can be found in Bailey (1982).

1. General Principles

Wildlife management is an art. Data for making wildlife management decisions may be collected, analyzed, and communicated using the methods of science. However, because of the complexity of the resource, such data is rarely adequate to predict consequences of management actions with certainty. Management, therefore, requires using this information in combination with experience and judgment to design actions that are most likely to achieve defined goals. Furthermore, due to the uncertainty, prudent managers with no previous local experience will begin with limited management actions, and will measure the efficacies of their treatments for achieving goals. The planned measurement of treatment effects provides new knowledge as a basis for making future management decisions. Treatment may be abandoned, modified, or expanded, depending upon their measured values in achieving goals. In this way, management is a cyclic, incremented process.

Models, such as the forage allocation model presented in Section VII can be powerful tools for integrating data and making quantitative predictions. However, results of modeling efforts should be used just as data from other sources, i.e., in combination with experience and subjective judgment. A model that has been used extensively with satisfactory results should be relied on more than one which is new and relatively untested. Barrett and Salwasser (1982) describe the use of simulation models in combination with monitoring to assist in management of wildlife habitat.

Wildlife management should be goal-oriented. Many wildlife management efforts, particularly habitat improvement programs, have failed because goals have been defined vaguely or not at all, and/or because methods have been confused with goals. Improving habitat for bighorn sheep is a method, not a goal. Increasing a bighorn herd by 20% is a well-defined goal.

Finally, wildlife goals can seldom be achieved without management of limiting factors, e.g., those factors of the environment that limit the growth or productivity of a population. The concept of limiting factors is a basic tenet of ecology (Odum 1959) and is the basis for wildlife management (Leopold 1933). Yet, many management plans lack analysis of limiting factors and recommended management techniques often appear unrelated to manipulation of limiting factors.

2. Implications of General Principles

Because wildlife management is an art and data are usually limited, the management recommendations are based partly upon knowledge and experience from other areas and on subjective judgment. Recommendations are therefore conditional predictions that should be implemented incrementally while testing their efficacies. Thus, recommendations presented here are based upon general knowledge of ungulate biology and on experience with ungulate management as well as on analysis of Trickle Mountain data and results of simulation modeling.

Because predicitons are tentative, monitoring is a key part of management. Monitoring includes the collecton and analysis of data to determine the effectiveness of management. Recommended monitoring procedures for the Trickle Mountain area, subsection F, relate to goals and treatments described in subsection C and E, respectively.

C. Management Objectives and Alternatives

1. HMP Objectives - Management objectives for ungulates on the Trickle Mountian area as stated in the Habitat Management Plan (Prichard et al. 1977) are:

   a. Bighorn Sheep

      (1) Improve habitat conditions within the WHA to support the bighorn sheep population which utilizes the crucial winter range around Trickle Mountain from 300 to 350 head (or to 500 head if it becomes possible later without precipitating a lungworm-related dieoff).

      (2) Protect 1,800 acres of crucial bighorn sheep winter range and provide additional winter forage.

   b. Pronghorn

      Improve or maintain about 40,000 acres of yearlong pronghorn range to allow for an increase in the WHA pronghorn population from the present 100-125 in 5 years.

   c. Mule Deer

      Improve habitat conditons on 20,000 acres of crucial mule deer winter range and 60,000 acres of year-long range to allow for an increase in the deer population from the present maximum of 500 to a maximum of 750 in 5 years.

   d. Elk

      Improve or maintain habitat conditions on 60,000 acres of winter elk range within the WHA to allow for an increase in the elk population from the present 300-350 to 350-400 in 5 years.

   e. General

      An objective with regard to wildlife oriented recreation has been to improve 60,000 acres of Public Lands within the WHA to enhance the area for wildlife and support 2,500 big game hunter-days per year (Prichard et al. 1977).

2. Alternative Objectives

Based upon results of this study, we suggest the following modified and/or alternative objectves be considered. Any or all of these alternatives could be selected.

(a) Bighorn Alternative

Increase the bighorn sheep population from an estimated 300-350 head to 500-600 animals.

(b) Pronghorn Alternative

Increase the pronghorn population from an estimated 150 to 300 animals.

(c) Elk Alternative

Increase the winter-spring elk population from an estimated 500 to 1,000 head.

We believe these objectives could be achieved without a reduction in the total amount of livestock grazing on the study area and without any drastic reduction or modification of other uses of the area.

D. Limiting Factors

1. Bighorn Sheep

McCollough (1982) indicated possible limiting factors for the Trickle Mountain herd as winter forage, summer forage, water, predation, and disease. He suggested that water and summer forage were abundant and available to bighorn sheep and were unlikely to be limiting. Although predation has not been investigated, there is no evidence of significant predation on the herd.

Many studies have suggested that disease, particularly pneumonia, may limit bighorn populations (Spraker and Hibler 1982). However, there was no evidence that disease was a factor limiting the Trickle Mountain herd during this study (1978-79). The population was being treated for lungworm, and although there was a minor outbreak of soremouth (contagious ecthyma) in 1979, there was no evidence of substantial mortality.

The combination of hunting and removal by trapping for transplanting may be limiting the western segment of the herd. Geist (1975) hypothesized that hunting, even male only hunting, of bighorn sheep may be detrimental. In the Trickle Mountain area, trapping and transplanting of sheep is probably a more significant impact, since adult females are removed. Bighorn sheep have a low reproductive potential since ewes typically do not give birth until age 3 and

and generally produce only one lamb per year. With such a low reproductive potential, removal of even a small percentage of females could substantially affect population growth.

Winter-spring forage may be limiting the bighorn population. McCollough (1982) analyzed the problem in detail and suggested that an additional 116 bighorn could be supported by limiting cattle grazing on critical bighorn habitats. This conclusion has not been substantiated with the simulation model. However, the model has not been used to analyze the bighorn situation in the detail used by McCollough (1982). Therefore, recommendations for bighorn sheep are based upon McCollough's report. The working hypothesis is that winter-spring forage is the factor limiting the bighorn population but that some relaxation of the harvest/removal rate may be necessary to allow the western segment of the population to increase.

2. Pronghorn Antelope

Productivity of the Trickle Mountain pronghorn herd is relatively low, as the herd has not increased substantially even with bucks-only hunting. Factors likely to be limiting pronghorns on Trickle Mountain include predation on fawns and forage quality.

Both bobcats and coyotes are common on the range and are a well-documented cause of significant fawn mortality in other areas (Beale and Smith 1973; Von Gunten 1978; Beale 1978). The period from birth until one month is critical since at this time kids move little, remain hidden, and are potentially very vulnerable to predation. Several studies have suggested that predation loss is most severe during this period (Bodie 1978; Barrett 1978; Von Gunten 1978) and several workers have suggested a relationship between vegetative structure on fawning areas and predation (Bodie 1978; Beale 1978; Von Gunten 1978; McNay and Ogara 1982). A brief investigation of fawning areas on Trickle Mountain suggested they may be suboptimal due to heavy grazing and resulting sparse vegetative cover; however the relationship is not well documented (Hoover 1979).

Simulation modeling suggested that nutritional quality may limit the pronghorn population. The range has a limited amount of perrennial forbs and the diet of Trickle Mountain pronghorns is low in forbs. This is typical of pronghorn herds on limited ranges (Yoakum 1979). Most of the pronghorn herd spends the entire year on BLM lands. However, during the dry summer of 1978 many antelope moved to higher elevations on or bordering Forest Service lands. Many of these areas were fairly heavily timbered and appeared to be suboptimal in terms of pronghorn's normal preference for very open habitat. It appeared that the pronghorn were doing this to take advantage of the more succulent nutritious forage in such areas, thus suggesting that summer as well as winter forage may be of suboptimal quality in their preferred habitat.

Thus, the working hypothesis is that year-round forage quality, perhaps in combination with suboptimal fawning habitat, is limiting the pronghorn herd.

3. Mule Deer

Probable factors limiting the mule deer herd on Trickle Mountain include hunting, quality of winter/spring forage, and/or competition from elk.

Heavy either-sex hunting was believed by some (Hansen 1979) to have caused a reduction from the high density of the Trickle Mountian deer population of the 1960's. However, more restrictive antlered-only harvest for the last 10 years has apparently not resulted in a return to the earlier high densities. In any case, it is unlikely that current antlered-only harvest is limiting the deer population.

Quality of winter and/or early spring forage is the most likely limiting factor. The range supports little good deer browse, such as mountainmahogany. During the severe winter of 1979, estimated diets of deer contained 40% conifers (Douglas-fir, juniper and pine) which are relatively unpalatable and undigestible. Even during the relatively mild winter of 1978 conifers comprised 26% of the deer diet. Simulation analyses also suggest that deer are limited by forage quality. Furthermore, the supply of cool-season grasses and forbs on the range appears to be depleted, resulting in suboptimal spring forage for deer.

If competition between elk and deer is significant in this area, then it would most likely be for good winter browse. Therefore, competition from elk cannot be separated from winter browse as a factor limiting deer populations. The apparent decline in deer density has coincided with a steady increase in elk numbers.

The working hypothesis is that deer are limited by forage quality, primarily by a limited supply of good winter browse and early season forbs, and that competition from elk may be partly responsible for this shortage.

4. Elk

The factor most likely limiting the elk herd is antlerless hunting. Simulation analyses suggested that both forage quantity and quality are adequate, but that harvest of antlerless alk is sufficient to limit population growth.

Our field data and field observations supported this contention. In particular, there was no evidence that quality of winter forage, the other potential limiting factor, was inadequate. During the severe winter of 1979, elk were able to switch to a diet composed of 50% grasses and there was no evidence of a significant die-off.

Thus, habitat does not appear to be limiting the elk population. This is confirmed by Colorado Division of Wildlife ONEPOP simulation runs (Olterman 1980).

E. Recommendations for Management

1. HMP Objectives

a. Bighorn Sheep
b. Pronghorn Antelope
d. Elk

The HMP objectives for population numbers of these species have been achieved, as best can be determined without a precise census. The Colorado Division of Wildlife estimates there are at least 350 bighorn on the area now. There are clearly at least 125 antelope on the area year-round and at least 400 elk wintering on the area. Thus, to achieve the current objectives for these species, no change in management is recommended.

c. Mule Deer

The objective of achieving a mule deer population of 750 animals probably has not been achieved. Our best estimate of the number of mule deer wintering on the area is 500 animals.

Assuming that high quality winter-early spring forage is limiting the deer population, then increasing the production of good winter browse and of early-season grasses should increase the productivity of the herd.

Of the native browse species on the range, true mountainmahogany would be the first choice to manage for increased production. It is highly preferred by deer in the area, it grows in habitats that deer use readily, and studies from other areas indicate that it is highly nutritious and digestible by deer. However, such management is probably not feasible. The species is so depleted on the range and is so highly preferred by the other ungulates that it is unlikely to be reestablished in sufficient density to provide a significant increase in the amount of deer forage.

Secondary choices for management are fringed sagebrush, winterfat, and saltbush. The latter two might be increased through reseeding. Both are preferred by deer and are highly nutritious. They are best adapted to the calcareous soils of limey benches (SCS Range Site No. 276) which consititute a significant proportion of the study area. Furthermore, many of these sites are at lower elevations in relatively treeless areas that are used heavily by deer but only lightly by elk. Finally, techniques for reseeding or reestablishing such species have been developed (Aldon 1970; Kay et al. 1977a; Kay et al. 1977b; Plummer et al. 1966; Plummer et al. 1968; Riedl et al. 1964; Springfield 1970; Stevens et al. 1977). However, fourwing saltbush was not successfully established in the only test seeding on the Trickle Mountain area. The SCS indicates that limey bench sites in the area may be vegetated by up to 50% winterfat and 10% fourwing saltbush, by weight, and that such sites have a potential production of about 600 pounds per acre during average years.

Increasing production of cool season grasses and palatable forbs is the best opportunity for increasing high quality early-spring forage. Comparison of forage production data with range site descriptions suggests that the range has been depleted of certain cool season grasses, especially western wheatgrass and Indian ricegrass. BLM records indicate that Indian ricegrass in the area has an earlier phenology than do other common cool season species. The SCS study of reseeding methods indicated that both of these species can be established on the area (Hassell 1979). Since these are among the earliest species to green up and are relatively palatable and nutritious for deer during the critical early spring period, they are recommended grasses for a seeding mixture.

It is recommended that at least one forb species be included in a seeding mixture. A dryland legume such as Ladak alfalfa would be most nutritious for deer. This variety is noted for responding to grazing by developing a prostrate growth form. This is desirable as it would make the alfalfa less susceptible to depletion by grazing when seeded with grasses in areas grazed by livestock.

The value of fringed sagebrush for all wild ungulates on the area has been mentioned. This species is highly palatable and nutritious to most species of wild and domestic ungulates, yet it tends to increase with site disturbance, due in part to its very prolific production (Cooperrider and Bailey 1982). Therefore, any seeding that involves surface preparation or disturbance is likely to increase the production of fringed sagebrush.

In summary, to increase deer productivity, we recommend a mixture seeding of winterfat, fourwing saltbush, western wheatgrass, Indian ricegrass and Ladak alfalfa on limey bench range sites where use is primarily by deer and not elk. Information available to us suggests that such seedings are feasible for the Trickle Mountain area. However, we recommend that a more in-depth evaluation of feasibility be conducted by range conservationists with expertise in such methods.

We believe that such seedings, if successful, could allow the mule deer wintering on the area to increase from 500 to 1,000 animals. We are not recommending that this be done. A decision to reseed for deer should involve consideration of costs and benefits of the project, weighed against other priorities. Rather, we suggest that such seedings are the most practical and feasible method for achieving the objective of increasing the deer herd.

2. Alternative Objectives

a. Bighorn Sheep

An objective of allowing the bighorn sheep herd to increase to 500-600 animals apparently could be achieved through a combination of reseeding, redistribution of livestock grazing, and limited removal of female bighorn from the area.

Reseeding with mixtures proposed for deer could be done on the critical winter-spring bighorn areas described by McCollough (1982). In addition, the impact of cattle on these critical areas could be minimized by (1) fencing, (2) the development of water at other sites, and (3) the removal of cattle from such areas in early September to reduce utilization of browse species important to bighorn sheep.

Such management should increase both the quantity and quality of forage available to bighorn during the critical winter-spring period. To allow the population to increase, the removal of bighorn sheep from the area through trapping and transplanting should be reduced or halted until the desired population level has been reached.

b. Pronghorn Antelope

Reseeding pronghorn habitat with mixtures proposed for mule deer should substantially improve the quality of forage available to pronghorns. Such seedings could allow for an increase in the antelope population from roughly 150 to 300 animals.

In addition, livestock grazing should be adjusted, where possible, to ensure that pronghorn fawning areas retain or develop adequate vegetative cover for fawns during the critical first month of life. This will require more intensive delineation of fawning areas.

c. Mule Deer

Methods for attaining an alternative mule deer objective of 1,000 animals have been discussed under HMP objectives.

d. Elk

The alternative objective of allowing elk numbers to increase to 1,000 can be achieved by eliminating the antlerless harvest on elk for approximately 5 years. After that period, previous harvest rates for antlerless elk could be resumed with approximately 100% increase in total harvest. Modification of the harvest rate is a responsibility of the Colorado Division of Wildlife (CDOW). There is a need with this species, as with the others, to develop coordinated BLM-CDOW objectives for the area.

3. Discussion

The original study objectives included an analysis of potential habitat improvements including, but not limited to, vegetative manipulation, controlled burning, fencing, seeding and planting, and of livestock grazing systems, big game harvest, and trapping and transplanting. Analysis of limiting factors and of feasbile management practices suggested that only two methods, big game harvest and seeding, are likely to result in meeting HMP or alternative big game objectives. However, brief mention of other methods and their potential, or lack thereof, to increase big game populations is in order.

The potential on BLM lands within the study area for improving habitat through vegetative manipulation, other than seeding and planting, is very limited. Forested habitat is quite limited and in many areas manipulation of trees to increase forage would result in loss of important cover for deer and elk. There may be opportunities to improve visibility for bighorn sheep along migration corridors by tree removal. However, these corridors have not been identified in the study area. Browse stands are also very limited and are primarily in areas where topography prevents mechanical manipulation.

Similarly, burning does not appear to have much potential. As with mechanical manipulation, burning might remove important forest cover, and burning of shrub stands does not appear feasible, since they are widely scattered and typically in rocky terrain with sparse fuel. Burning of grasslands has been suggested as a tool for improving bighorn and elk ranges. However, grassland burning on this area appears neither feasible nor desirable. Vegetation in most grasslands is so sparse that there probably is not enough fuel to carry a good fire. Burning to improve range for wildlife has been most successful on mature grass stands where setting back succession results in additional production of forbs and of nuturtious young grass plants. Succession on the grasslands of the study area has repeatedly been set back by livestock grazing, and controlled burning is unlikely to cause an increase in nutritious forage.

Fencing could be used in a few locations to exclude livestock from key bighorn areas, as mentioned above. Otherwise, the opportunities to use fencing to attain wildlife objectives are limited.

Use of grazing systems to achieve wildlife objectives has been addressed at the allotment level in separate recommendations provided to the area office. In general, systems favoring increased production of cool-season grasses and forbs, perennial forbs, and/or palatable browse species should benefit the wild ungulates on the area.

There are no obvious opportunities for trapping or transplanting. Transplanting has been used successfully to establish bighorn sheep in new areas or to establish new seasonal-use areas. However, bighorns in the study area have established many seasonally-used ranges naturally. This range expansion since the bighorn transplant of 1951 has been enhanced by the abundance of escape terrain and openness of the vegetation on the study area.

With the exception of elk, only male ungulates are harvested on the study area. Harvests are therefore unlikely to be limiting populations other than elk. As mentioned earlier, a reduction in the antlerless elk harvest should allow the population to increase.

One additional management opportunity, control of human disturbance, requires mention. Both bighorn sheep and elk have been found to be sensitive to human disturbance, especially in hunted herds. Human disturbance, such as from off-road vehicles, can result in abandonment of traditional use areas and increased stress on individuals. It is our opinion that such disturbance is not currently a problem. However, it could get worse in the future and require remedial action. The most likely problems would be from increased vehicular travel on winter ranges of sheep and elk by 4-wheel drives and/or snowmobiles.

In summary, the greatest opportunity for habitat improvement will be through seeding and planting, and the ungulates most likely to benefit from such action would be pronghorn antelope and mule deer.

F. Recommendations for Monitoring and Studies

The form of future monitoring and studies will depend partly upon the objectives of management and the techniques chosen for habitat modification. However, some monitoring techniques will be appropriate regardless of objectives. Recommendations for monitoring will be discussed as general recommendations and as recommendations by species.

1. General Recommendations

a. Vegetation Monitoring - Continued monitoring of the vegetation will be necessary to ensure that forage production is adequate to support the numbers of ungulates present or desired. This can be done most efficiently by concentrating on key species and key areas. Recommendations for key species and areas (Table 22) suggest that four grasses (Arizona fescue, blue grama, and 2 muhlies--M. montana and M. filiculminis), two shrubs (fringed sagebrush and fourwing saltbush), and perennial forbs are critical forages for the ungulates. Thus monitoring should concentrate on determining condition and/or trend of these species.

Table 22. Key areas and key plant species recommended for intensive monitoring to determine habitat condition for Trickle Mountain ungulates.

Ungulate species	Key areas	Key plant species
Bighorn sheep	Winter/spring range	Fringed sagebrush, Arizona fescue, blue grama, muhlies
Pronghorn antelope	Spring/summer range	Fringed sagebrush, perennial forbs
Mule deer	Winter/spring range	Fringed sagebrush, fourwing saltbrush
Elk	Winter/spring range	Fringed sagebrush, Arizona fescue, muhlies

Other plant species, which are not now major components of the diet, but which could become more important with improved grazing management, include winterfat and wheatgrass (A. cristatum and A. smithii). It would be appropriate to also monitor trends of these species.

Obviously, any seeding should be monitored for all plant species in the seeding mixture.

b. Habitat Use and Food Habits - If a seeding is tested or implemented, use of the treated area by wildlife should be monitored. Likewise, food habits of the animals in the area should be determined through fecal analysis or another appropriate technique. These data should be adequate to determine if the seeding has resulted in a shift in habitat use or food habits. The assumption is that such a shift would result in improved nutritional quality of the animal's diet and ultimately in a population response. Therefore, a monitoring program should include measurement of population parameters before and after treatment.

c. Population Response - Since the ultimate objectives of wildlife management are usually stated in terms of animal numbers, periodic censuses are best for determining if objectives have been met. However, censuses of many big game species are often difficult and of questionable accuracy. Therefore, estimates of other population parameters, such as fawn or lamb recruitment, may provide better indications of the efficacies of management actions. Appropriate measures will be discussed below for each species.

d. Human Disturbance - Human disturbance from off-road vehicle travel by 4-wheel drives, motorcycles, and snowmobiles should be monitored, especially on winter ranges of bighorn sheep and elk.

2. Species Recommendations

The following recommendations include monitoring of populations as well as habitat. We recognize that monitoring populations has traditionally been a responsibility of the state wildlife agency. However, interagency planning and cooperation can enhance efficient achievement of all monitoring goals.

a. Bighorn Sheep

McCollough (1982) recommended two ways to test the hypothesis that cattle grazing limits expansion of the bighorn sheep herd. One of these approaches could be chosen. In any case, the areas critical to bighorn should be considered as key areas for monitoring condition and trend of vegetation. Critical areas for bighorn are the winter-spring ranges outlined by McCollough (1982) and the lambing areas on BLM lands. There is some overlap between them. These areas should also be monitored to determine if disturbance such as mining exploration or off-road vehicle use is occurring.

Continued monitoring of winter-spring food habits of bighorn each winter and spring could be useful in interpreting any habitat changes and their effects on sheep. There is strong evidence that the browse species, fringed sagebrush and fourwing saltbush, are key forages for bighorn during the critical winter-spring period when grass is dormant. A reduction in the percentage of these forages in the winter-spring diet of sheep would suggest declining dietary quality.

Study of the movements of bighorn on the area would be useful. Although some knowledge of their movements has been obtained, a more thorough investigation is warranted. For example, intermediate ranges and migration corridors used by bighorn moving to summer ranges on Antora Peak are not well delineated. Continued monitoring of movements would be most useful in interpreting effects of disturbance and habitat changes as well as variation in food habits.

Finally, the population size and productivity should be monitored regardless of whether the chosen objective is to maintain or increase the herd. An annual census would be desirable. Data on productivity and recruitment, i.e., ewe:yearling:lamb ratios, should be collected annually for both eastern and western segments of the herd.

b. Pronghorn Antelope

If a seeding is implemented for the benefit of deer or antelope, the population and the treated area should be monitored to determine if the seeding is being used, if food habits have changed as a result of the seeding, and if such change is resulting in increased productivity. The latter could be estimated by obtaining fall doe:kid ratios.

An annual pronghorn census would be desirable. Aerial censuses of the unit are conducted by the Colorado Division of Wildlife. This technique, which has proven useful with antelope in many other areas, tends to underestimate antelope numbers on this study area. However, aerial trend counts could be considerd as indexes of relative density. Since hunting is on a permit basis, information on total harvest is of limited value. However, data on harvest per unit effort such as percent success or hunter-days per animal harvested could be used to corroborate the population indices. The assumption is that harvest per unit effort will be correlated with population density.

c. Mule Deer

If a seeding is implemented, then habitat use, food habits, and herd productivity should be monitored for deer in the same manner as for pronghorn.

Census of deer will be extremely difficult in the study area without extensive marking of animals. However, since deer are hunted in the area on a regular license, i.e., without variable numbers of specified permits, then both total harvest and harvest per unit effort (hunter success) would be useful indexes to estimate population trend.

d. Elk

Without evidence of a habitat factor limiting elk, monitoring could be minimal. Regardless of the population objective, key elk wintering areas such as the north side of Trickle Mountain, should be monitored for vegetation condition and trend to ensure that the habitat is not deteriorating. Similarly, hunter harvest should be monitored to ensure that population objectives are being met. The Colorado Division of Wildlife uses aerial trend counts annually to determine population trend and calf:cow ratio.

G. Recommendations for Research and Development

The following listing of research needs relate primarily to the general problem of forage allocation. They represent general information needs that were identified during the study. These needs could be addressed through research.

1. Techniques for Determining Food Habits.

Current forage allocation procedures utilize proper use factors (PUF's) to estimate food habits. Since PUF's have never been scientifically determined (Skiles et al. 1980b) and were intended to be site-specific, widespread use of generalized PUF tables to predict food habits is a questionable practice. As part of this study we demonstrated that fecal analysis is a practical cost-efficient method of estimating food habits (Cooperrider et al. 1981b). However, the accuracy of the technique continues to be controversial. There is a need to assess the accuracy of the technique.

2. Prediction of Food Habits.

Knowledge of food habits is important for forage allocation as well as for many other purposes. Since food habits are often site-specific (Cooperrider et al. 1981a), they must either be determined seasonally on every game range, allotment, and/or pasture, or methods for predicting food habits must be developed. Given data on the species of foraging ungulate and the relative abundance and phenological stages of the available forages, we have observed that experienced rangemen or wildlife biologists can often predict food habits with reasonable accuracy. This suggests that more systematic methods for making such predictions can be developed through research. Since the above data (ungulate species, phenology and abundance of major available forages) are collected as part of SVIM, then development of such a technique would obviate the need to determine food habits directly on every range.

3. Prediction of Habitat Use.

One of the greatest problems in predicting or quantifying utilization of forage on a range is predicting the habitat or areas utilized by an animal or a group of animals. This is true for both livestock and wildlife. Most systems for predicting or quantifying habitat use have been limited to designating areas and/or habitat types as used or not used (suitable/unsuitable) on a seasonal basis. In reality, habitat utilization does not result from such rigid preferences. Simple practical techniques need to be developed for animal distributions and using them, together with habitat data, to predict habitat use.

4. Effect of Livestock on Distribution of Wild Ungulates.

Many workers have observed that certain wild ungulates will avoid areas utilized by domestic livestock (Mackie 1978). This has been mentioned most often for bighorn sheep, elk, and cattle. However, data on occurrence of such phenomena is contradictory. If such a response is real, then it has important implications for forage allocation. Research is needed to determine under what environmental circumstances such avoidance occurs and what is the proximate cause of the avoidance.

5. Determination of Forage Intake Rates.

Forage intake rates are important inputs for forage allocation for two reasons. In most systems intake rates are used to predict amounts of vegetation being removed by the foraging animals. However, intake rates may also be used, together with nutrient compositions of forages, to predict nutrient intakes by foraging animals. Forage intake rates, however, are functions of many factors, including animal species, sex, body weight, forage quality, and season (Skiles et al. 1980; Zarn 1981). There is a need for research to improve methodology for predicting ungulate intake rates under varying environmental conditions.

6. Relationship of Nutritional Plane to Survival and Reproduction.

   In Section VII, we discussed the relationship between forage quality and population dynamics. This is a most important relationship in ungulate ecology and management, yet it has been most difficult to quantify and model. Research is needed to improve techniques for predicting the impact of nutritional plane and animal condition on reproductive rates, and subsequent survival of young.

7. Effect of Previous Grazing on Nutritional Quality of Remaining Forage.

   It is well established that utilization of a range beyond a certain level will result in both decreased total intake by livestock and decreased nutritional quality of the ingested forage (Cook et al. 1953; Pieper et al. 1959). This relationship is also likely to be true for wildlife. Research is needed to develop methods for quantifying this relationship for both livestock and wildlife so that impact of grazing on nutritive quality of the diet can be predicted.

H. Recommendations For Simulation Model Development

1. Background

The specification of objectives in the Trickle Mountain contract states that "a major effort...will be the development of a forage allocation system and model to be considered by the Bureau for use as an approved forage allocation method for field offices." The model has been described in detail in Section VII with a rationale for its development and an analysis of its strengths and weaknesses. It is appropriate here to repeat, from a "post-development" perspective, what we perceive as the strength, utility, and limitations of the model as well as our recommendations for future use and/or development.

a. Use of Models in Natural Resources Management - Models have been used in natural resources management for many years. For example, the techniques for calculating gross carrying capacity, described in Section VI are simple calculation models. In the past 20 years, deployment of high speed digital computers has allowed development of more complex models that can incorporate more realism and also handle much larger volumes of data.

The technique applied to the forage allocation problem is computer simulation. Computer simulation has been successfully applied to a wide range of natural resource problems including forestry, range management, fisheries and wildlife management. See, for example, Clutter and Bamping 1965; Leak 1970 (forestry); Gilbert 1975; Janeson 1970 (range); Paulik 1975 (fisheries); Connolly et al. 1971; Cooperrider and Behrend 1980; and Walters and Gross 1972 (wildlife).

In the last four years, the BLM has applied another technique--linear programming--to the forage allocation problem. This is one of a set of techniques termed "optimization models." A brief comparison of the two techniques may clarify their different approaches.

b. Comparison of Simulation and Optimization Models - The linear programming model, hereafter referred to as the "optimization model" utilizes the same data bases as the simulation model; however, the simulation model can use additional data bases (Table 23).

The purpose of the optimization model is to determine an optimal forage allocation as defined below. An optimal forage allocation is one in which the maximum amount of the total annual forage production is utilized subject to given constraints. The variables in the solution are the number of animals of each ungulate species. The major constraint is that the plant requirements for sustained yield be met, i.e., that the allowable use factors not be exceeded for any plant species. The model is thus primarily designed to ensure that the requirements of forage plants are met. However, additional constraints may be added, the most important of which is that a minimum or maximum number of animals of a given ungulate species be supported. For example, a problem might be constrained so that at least 100 elk and/or 100 cattle be included in the "solution".

Table 23. Data Bases for Forage Allocation Systems.[1]

Data Base	Optimization Model	Simulation Model
Basic Data		
Forage Production	R	R
Animal Numbers[2]	R	R
Forage Intake Rates	R	R
Food Habits	R	R
Habitat Use	R	R
Supplementary Data		
Plant Requirements	R	0
Animal Requirements		0
Weather Data	0	0
Plant Nutrient Content		0
Animal Population Structure		0
Plant Dynamics		0
Animal Population Dynamics		0

[1] R indicates the data base is required; 0 indicates the data base can be used by the model but is not required.

[2] Animal numbers are used in optimization models to constrain the solution; they are used in simulation models to indicate the intital conditions.

The principal output from the optimization model is the number of animals of each ungulate species that can be supported on the range. These numbers can then be used by a land manager for adjusting livestock numbers on the range and/or recommending to the state agency that numbers of wildlife be increased or decreased. However, the model will also predict how much of the annual forage production of each plant species would be utilized with the "optimal" mix of animal species.

The simulation model attempts to mimic the grazing system over time. As such, it does not predict an "optimal" solution. Rather, given an initial state of the system (in terms of forage production and animal numbers) and a given management strategy, it will predict what the state of the system will be after a given period of time.

Outputs of the simulation model also include numbers of domestic and wild ungulates and forage utilization. However, since the model is dynamic (i.e., the system is simulated over time), these outputs can be obtained after any given interval (i.e., 1 month, 3 months, 1 year, 5 years, etc.). For example, the predicted number of elk supported on a range might be much different after 5 years than after 1 year. In addition, because the model utilizes more complex data bases, the outputs may also be more complex. For example, the number of elk surviving after 5 years may be classified by sex and age.

A unique feature of the simulation model is that it attempts to relate forage allocation to the nutritional requirements of the wild ungulates. Furthermore, it can incorporate data on population dynamics. Thus, data on nutritional measurements of plants and nutrient requirement of animals are used to link a habitat model with a population model.

Clearly, the two models operate quite differently and can serve different purposes. Similarly, to the extent that they use the same data bases, the quality of the input data is not an issue in comparing them. Given poor input data, both models can produce erroneous outputs.

A major advantage of the optimization model is that it produces directly an "optimum" allocation, i.e., a solution. However, it is not particularly useful for understanding the nature of the grazingland system or for investigating the effects of varying environmental conditions or alternative management strategies. However, where the major concern is the amount of forage of varius species allocated to big game and livestock, then the optimization model is a good tool for quickly arriving at and/or justifying an allocation decision.

When the allocation problem is more complex and/or when one is more concerned about understanding the system than about arriving at an immediate decision, then a simulation model may be more useful. Simulation models are being used in this manner for decision-making in many natural resource fields such as forestry (Foster 1973), fisheries (Silliman 1969), and recreation (Lucas and Shechter 1977) as well as wildlife (Pojar and Strickland 1979; Willliams 1981).

c. Strengths and Weaknesses of the Simulation Model - The simulation model, described in Section VII, consists of a "habitat" submodel linked to a "population" submodel. Forage removal and the effect of the nutritional quality of such forage on populations provide the linkages between the submodels. These submodels will be discussed separately.

The population submodel is similar to population models such as ONEPOP (Gross et al. 1973) and POPMOD (Dean and Gallaway 1965) now routinely used to assist state wildlife agencies in determining big game harvest strategies (Pojar and Strictland 1979). In fact, a system such as ONEPOP could be substituted for the population model we developed, and this is one of our recommendations. In general, however, the concepts and technology incorporated into the population model are well established and in use by many agencies.

The habitat model as it is now is not dynamic in the sense that the annual forage production and phenology do not change from year to year. However, as our understanding of the effects of rest and/or of overgrazing on forage production and species composition increases, this knowledge can be incorporated into the model making it dynamic.

A major strength of the model is that it links a habitat model with a population model, thus allowing prediction of impacts of ungulate populations on their habitat and vice versa. This is also the weakest part of the model in that the relationships modeled are not well understood or documented. However, the importance of these relationships in ungulate ecology dictates that efforts be made to quantify them. On the other hand, the model needs to be made more flexible so that as new knowledge on the effect of nutrition upon survivial and reproduction of ungulates becomes available, this information can be incorportated into the model.

The model has other strengths. It allows incorporation of a large body of scientific information, particularly on animal nutrition and on ungulate population dynamics. In addition, it is tailored to utilize site-specific data on forage production and animal population densities and structures. As such it can incorporate a great deal of realism and is adaptable so that new knowledge or relationships can be added in the future. Because the model is not an optimization model, it is not limited to analyzing any one allocation objective, but can be used to gain insight and make quantitative predictions about a wide variety of situations and management options.

The recent emphasis on monitoring by federal agencies provides additional rationale for development of simulation models such as the one described. Ecological systems are dynamic and our ability to predict such change with models is limited. Thus it is necessary to periodically compare actual results of management actions with predicted results. Since optimization models treat systems as if they are static, their utility in predicting and/ or interpreting change is minimal. Simulation models, on the other hand, can provide a powerful tool for predicting change under dynamic conditions and for interpreting monitoring results. The utility of using simulation models in conjunction with a monitoring program has been described by Barrett and Salwasser (1982) and Cooperrider and Behrend (1974) for forest/wildlife situations. The simulation model developed as part of this project could provide the BLM with a powerful tool for interpreting results of monitoring rangeland resources.

2. Recommendations

We suggest that the BLM continue refinement and development of the simulation model by implementing the following:

a. Recommendation: Convert the model to the Service Center's computer. Make the model interactive and conversational and available to field offices.

Rationale: The need for and/or utility of the model can best be evaluated by those who are eventual users; until the model is available and readily accessible, field offices will not be able to determine if it meets their needs.

b. Recommendation: Modify the population submodel to incorporate ONEPOP to the maximum extent possible.

Rationale: The population model ONEPOP is widely used and accepted in the wildlife field. It is also more flexible in terms of inputs and parameters than is the current submodel. Incorporation of ONEPOP would not only make the model more flexible but would result in more immediate acceptance of this submodel. In addition it would make ONEPOP available to BLM users that desire to use it separately for population analyses.

c. Recommendation: Modify the model so that it is more flexible in terms of inputs and outputs.

Rationale: Making the model more flexible will allow users who have limited data or who are interested in using only part of the model to utilize the model for a variety of purposes.

d. Recommendation: Select at least three test areas and collect habitat and population data to test the precision and accuracy of model predictions.

Rationale: Validation is needed to evaluate the model and to suggest improvements or refinements. Validation studies in several areas with different habitats and ungulate species will allow evaluation of the relative performance of the model in different environmental settings.

3. In summary, our limited testing of the model suggest that it could be a valuable tool for BLM wildlife biologists and range conservationists. We recommend that the BLM make the model operational, test it in the field, make appropriate modifications and refinements, and conduct validation studies.

IX. SUMMARY AND CONCLUSIONS

Results of the Trickle Mountain research project are reported here. The purposes of the study were to: (1) determine food habits, habitat use and dietary overlap of bighorn sheep, pronghorn antelope, mule deer, and elk, as well as domestic horses and cattle on the Trickle Mountain wildlife habitat area, (2) map vegetation and determine species composition and forage production, (3) determine gross carrying capacity for all ungulate species, (4) suggest range habitat improvement practices, and (5) develop a forage allocation system. The first four objectives were site-specific, related to the Trickle Mountain area. The fifth objective, to formulate a system that could have application in other areas, was more general.

Seasonal food habits of ungulates were determined using fecal analysis. Food habits varied substantially among seasons and years. The single most important plant species in the diet was fringed sagebrush. Other common items in the diet were grama, muhly, wheatgrass, fescue, mountainmahogany and winterfat. Spring dietary overlap varied from 3% for horses and mule deer to 76% for bighorn sheep and elk. Dietary overlap was highest in winter and lowest in summer. The variability in diets suggests the need for allocation systems that can account for both the selectivity and the adaptability of ungulate species in selecting forage. However, dietary overlap by itself is a poor measure of competition and an inadequate basis for forage allocation in the absence of additional data.

Observations of animals from the ground and from aircraft were used to delineate boundaries of seasonal ranges for each of the four wild ungulates on the Trickle Mountain study area. Due to the diversity and interspersion of habitat types, correlations of such observations with habitat features and/or vegetation types and with weather conditions was impractical. Seasonal ranges used by each ungulate species and the use of particular habitat types within such ranges generally conformed to reported habitat preferences of the species in other areas. Seasonal ranges as mapped from direct observation were the most practical measures for incorporating ungulate distributions into a forage allocation model.

Gross carrying capacities for all ungulate species on BLM lands within the Trickle Mountain study area were calculated from data on forage production with the use of allowable use factors (AUF's) and proper use factors (PUF's). Estimates for carrying capacity of the Trickle Mountain study area based on these techniques were 20,068 and 8,081 AUM's respectively. This compares with current licensed livestock use of 3,247 AUM's. Current wildlife forage use was estimated at between 2,417 and 5,867 AUM's depending on the AUM equivalent figures used. These figures yield total forage demand, of 5,664 and 9,114 AUM's (from livestock and wildlife) respectively.

Limitations of the AUF and PUF methods are discussed. A number of important biological processes are not considered by either method, including forage quality, population dynamics, foraging behavior and weather patterns.

A simulation model was developed for use by the BLM in analyzing forage allocation strategies. An attempt was made to incorporate a high degree of realism into a quantitative model that would use site-specific field data on forage production and ungulate populations and that could eventually be used operationally in field offices. A particular advantage of this simulation approach is that it can develop predictions about a variety of forage allocation alternatives or objectives and the associated biological consequences.

The model was constructed by borrowing ideas and concepts from existing models. Thus it incorporates in one model considerations of food and habitat preferences, plant dynamics, animal nutrition and animal population dynamics. Examples presented illustrate how the model can examine each of these phenomena either separately or in combination, provide insight into the plant-forage-animal system, and develop predictions about the effects of forage allocation alternatives.

Recommendations are made for both site-specific management practices and studies, and also for more general research and development related to the problem of forage allocation among competing species of wild and domestic ungulates. More research is required on: (1) techniques for determining and/or predicting food habits and habitat use, (2) the effect of livestock on distribution of wild ungulates, (3) forage intake rates, (4) the relationship of nutritional plane to survival and reproduction of wild ungulates, and (5) the effect of previous grazing history on the nutritional quality of remaining forage.

We recommend that the BLM make the simulation model operational, test it in the field, make appropriate modifications and refinements, and conduct validation studies.

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XI. PUBLICATIONS/PAPERS RESULTING FROM TRICKLE MOUNTAIN RESERACH

The following papers and publications have been prepared as a result of the Trickle Mountain Research project. They are available from:

Allen Cooperrider
U.S. Bureau of Land Management
Service Center (D-470)
Building 50, DFC
Denver, CO 80225

Cooperrider, A.Y.
1982. Forage allocation for elk and cattle. Paper presented at Western States Elk Workshop. Flagstaff, Ariz., Feb. 22-24, 1982.

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1982. Fringed sagebrush (Artemisia frigida) - A review of its ecology, management, and forage value. Unpub. Manuscript, 24 pp.

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APPENDIXES

Appendix A. Common and scientific names of plant and animal species used in text.

	Common Name	Scientific Name
PLANTS[1]		
Grass and Grasslike Plants		
	Arizona fescue	Festuca arizonica
	Big bluegrass	Poa ampla
	Blue grama	Bouteloua gracilis
	Bluegrass	Poa sp.
	Bottlebrush squirreltail	Sitanion hystrix
	Crested wheatgrass	Agropyron cristatum
	Dropseed	Sporobolus sp.
	Fescue	Festuca sp.
	Grama	Bouteloua sp.
	Indian ricegrass	Oryzopsis hymenoides
	Mountain muhly	Muhlenbergia montana
	Muhly	Muhlenbergia sp.
	Needlegrass	Stipa sp.
	Oatgrass	Danthonia sp.
	Prairie junegrass	Koeleria cristata
	Rush	Juncaceae
	Sedge	Cyperaceae
	Sheep fescue	Festuca ovina
	Slimstem muhly	Muhlenbergia filiculmis
	Squirreltail	Sitanion sp.
	Western wheatgrass	Agropyron smithii
	Wheatgrass	Agropyron sp.
Forbs		
	Alfalfa	Medicago sativa
	Cinquefoil	Potentilla sp.
	Eriogonum	Eriogonum sp.
	Goosefoot	Chenopodium sp.
	Globemallow	Sphaeralcea sp.
	Hymenoxys	Hymenoxys sp.
	Ladak alfalfa	Medicago sativa, var. Ladak
	Lupine	Lupinus sp.
	Mustard	Brassica sp.

Appendix A. (cont.)

	Common Name	Scientific Name
PLANTS[1]		
Trees and Shrubs		
	Aspen	Populus tremuloides
	Buffaloberry	Shepherdia sp.
	Cactus	Cactaceae
	Currant	Ribes sp.
	Douglas fir	Pseudotsuga sp.
	Fourwing saltbrush	Atriplex canescens
	Fringed sagebrush	Artemisia frigida
	Juniper	Juniperus sp.
	Mountainmahogany	Cercocarpus sp.
	Pine	Pinus sp.
	Pinyon	Pinus edulis
	Pinyon pine	Pinus edulis
	Ponderosa pine	Pinus ponderosa
	Rabbitbrush	Chrysothamnus sp.
	Rose	Rosa sp.
	Sagebrush	Artemisia sp.
	Saltbush	Atriplex sp.
	True mountainmahogany	Cercocarpus montanus
	Willow	Salix sp.
	Winterfat	Eurotia sp.
	Yucca	Yucca sp.
ANIMALS		
Fish		
	Rio Grande Cutthroat	Salmo clarki virginalis
Birds		
	Black-billed magpie	Pica pica
	Clark's nutcracker	Nucifraga columbiana
	Common crow	Corvus brachrhynchos
	Common raven	Corvus corax
	Golden eagle	Aquila chrysaetos
	Gray jay	Perisoreus canadensis
	Pinyon jay	Gymnorhinus cyanocephala
	Prairie falcon	Falco mexicanus
	Scrub jay	Aphelocoma coerulescens
	Stellar's jay	Cyanocitta stelleri

Appendix A. (cont.)

	Common Name	Scientific Name
ANIMALS (cont.)		
Mammals		
	Abert squirrel	Sciurus aberti
	Bighorn sheep	Ovis canadensis
	Bison	Bison bison
	Bobcat	Lynx rufus
	Coyote	Canis latrans
	Deer	Odocoileus sp.
	Elk	Cervus canadensis
	Mule deer	Odocoileus hemionus
	Pronghorn antelope	Antilocapra americana
	White-tailed deer	Odocoileus virginianus

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[1] Plant names are from Scott and Wasser (1980).

Appendix B. Calculation of caloric density (kcal DE/) for maintenance of deer (*Odocoileus* sp.).

A predicted maintenance level of caloric density of digestible energy can be calculated from two equations. One equation predicts daily forage intake (FI) in grams as a function of metabolic body weight (MBW) or

$WT_{kg}^{0.75}$ as follows:

$$FI = k_1 \text{ X } MBW \qquad (1)$$

The second equation predicts daily weight change (WC) as a function of digestible energy intake (DE) and metabolic body weight (MBW):

$$WC = k_2 + k_3 \text{ X } (DE/MBW) \qquad (2)$$

However, DE will be equal to the caloric density of the forage (CD) expressed as kcal DE/g times the forage intake (FI). Thus one can substitute (CD X FI) for DE. Substituting in equation (2) yields:

$$WC = k_2 + k_3 \left(\frac{CD \text{ X } FI}{MBW}\right) \qquad (3)$$

Substituting equation (1) for FI and setting WC = 0 yields an equation with one unknown that can be solved for CD.

Using an average value for forage intake such as reported by Walmo *et al.* (1977) for yearling male mule deer provides:

$$FI = 71.4 \text{ X } MBW \qquad (4)$$

Ullrey et al. (1969) reported a growth equation for white-tailed deer of:

$$WC = -0.1933 + 0.00121 \text{ X } (DE/MBW) \qquad (5)$$

Combining these equations, setting WC to 0, and solving gives:

$$CD = 2.24 \text{ kcal/g} \qquad (6)$$

which may be interpreted as the caloric density necessary to maintain weight.

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